LIBRARY GUIDE

for

THE CHEMIST

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University of Michigan

First Edition

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INTERNATIONAL CHEMICAL SERIES

Louis P. Hammett, Ph.D., *Consulting Editor*

LIBRARY GUIDE *for* THE CHEMIST

A SELECTION OF TITLES FROM THE

INTERNATIONAL CHEMICAL SERIES

LOUIS P. HAMMETT, PH.D., *Consulting Editor*

Adkins and McElvain—
Elementary Organic Chemistry

Adkins, McElvain and Klein—
Practice of Organic Chemistry

Arthur—
Lecture Demonstrations in Genera Chemistry

Arthur and Smith—
Semi-Micro Qualitative Analysis

Booth and Damerell—
Quantitative Analysis

Briscoe—
Structure and Properties of Matter

Cady—
General Chemistry
Inorganic Chemistry

Coghill and Sturtevant—
An Introduction to the Preparation and Identification of Organic Compounds

Crist—
A Laboratory Course in General Chemistry

Daniels—
Mathematical Preparation for Physical Chemistry

Daniels, Mathews and Williams—
Experimental Physical Chemistry

Desha—
Organic Chemistry

Desha and Farinholt—
Experiments in Organic Chemistry

Dole—
Experimental and Theoretical Electrochemistry

Gibb—
Optical Methods of Chemical Analysis

Glasstone, Laidler and Eyring—
The Theory of Rate Processes

Griffin—
Technical Methods of Analysis

Hamilton and Simpson—
Calculations of Quantitative Chemical Analysis

Hammett—
Physical Organic Chemistry
Solutions of Electrolytes

Henderson and Fernelius—
Inorganic Preparations

Huntress—
Problems in Organic Chemistry

Leighou—
Chemistry of Engineering Materials

Long and Anderson—

Mahin—
Introduction to Quantitative Analysis
Quantitative Analysis

Mellon—
Chemical Publications

Millard—
Physical Chemistry for Colleges

Moore—
History of Chemistry

Morton—
Laboratory Technique in Organic Chemistry

Norris—
Experimental Organic Chemistry
The Principles of Organic Chemistry

Norris and Young—
Inorganic Chemistry for Colleges

Parr—
Analysis of Fuel, Gas, Water, and Lubricants

Reedy—
Elementary Qualitative Analysis
Theoretical Qualitative Analysis

Rieman and Neuss—
Quantitative Analysis

Robinson and Gilliland—
The Elements of Fractional Distillation

Schmidt and Allen—
Fundamentals of Biochemistry

Schoch and Felsing—
General Chemistry

Soule—
Library Guide for the Chemist

Steiner—
Introduction to Chemical Thermodynamics

Stillwell—
Crystal Chemistry

Stone, Dunn and McCullough—
Experiments in General Chemistry

Thomas—
Colloid Chemistry

Timm—
An Introduction to Chemistry

Wilkinson—
Calculations in Quantitative Chemical Analysis

Williams and Homerberg—
Principles of Metallography

Woodman—
Food Analysis

PRINTED IN THE UNITED STATES OF AMERICA

BOOKS

These are the masters who instruct us
without rods and ferules,
without hard word and anger,
without clothes or money.

If you approach them they are not asleep;
if investigating you interrogate them
they conceal nothing;
if you mistake them, they never grumble;
if you are ignorant they cannot laugh at you.

The library of wisdom, therefore,
is more precious than all riches,
and nothing that can be wished for
is worthy to be compared with it.

Whosoever, therefore, acknowledges himself
to be a zealous follower
of truth, of happiness,
of wisdom, of science,
or even of faith,
must of necessity make himself
a lover of books.

—Richard de Bury, "Philobiblon."
(Written in 1344, first published in 1474).

PREFACE

The literature of chemistry is probably more adequately classified, more thoroughly indexed, and more consistent in terminology than that of any other science. Yet location of chemical information beyond the purely obvious is not easy. Success depends largely upon knowing where to look and what to seek. Critical judgment is also an important element because the mere fact that one finds a statement "in print" is no guaranty of its validity. Furthermore the problem is not becoming simpler as time passes. One of the great barriers is the increasing volume of literature. The American Chemical Society now spends about two hundred thousand dollars annually just to summarize and index the fifteen hundred books, forty thousand articles, and twenty thousand patents of chemical interest that are published every twelve months. Incidentally the flood is rising at the rate of some six per cent a year, which means that the figures cited will be doubled before 1950.

After wrestling with the problem of finding chemical data for over a decade, I have become convinced of the value of training in library technique, i.e., acquisition of skill in the use of bibliographical tools, especially those peculiar to the field of chemistry. This book has been prepared in order to make my point as concrete as possible.

The text is primarily a guide to the use of keys and summaries. In this respect it is unlike the few other books dealing with chemical literature because they are mainly concerned with the cataloging of source materials. I have started with the arrangement of a library and its directories, intentionally neglecting problems of the librarian to emphasize those of the chemist. Next there is a section dealing with sources of biographical data. It is followed by a discussion of periodicals and the reading of original reports. Their initial summaries appear in abstract

use of author and subject indexes. The succeeding chapter is devoted to the product of the second condensation, viz., reviews and annual reports, which is followed by a survey of encyclopedias and dictionaries. The next four units contain material on textbooks divided into the conventional groups: inorganic, organic, analytical, and physical. After these chapters are sections on patent literature and government publications in general. The closing division includes material on report writing and the filing of notes.

The bibliography in almost every chapter is subdivided according to subject and arranged chronologically or alphabetically according to author. No attempt has been made to prepare a complete list or to mention only the "best" books in any division. My object has been rather to indicate the variety of reference material available; hence the absence of a title is no implication of unworthiness. Generally textbooks of an elementary nature have not been mentioned. Furthermore, books published since January, 1937, as well as those printed in languages other than English, French, or German, have received slight consideration. The book lists marked "References" at the end of certain sections comprise the sources chiefly used in assembling material for the chapter concerned.

This *Guide* was first prepared for my students, seniors and graduates specializing in chemistry at the University of Michigan. Their needs and helpful criticism of two mimeographed editions have tended to determine the scope of the text, eliminate some faults, and improve the parts found most useful. I am also indebted to many friends for helpful suggestions. Two well-known books on the subject, Crane and Patterson's "Literature of Chemistry" and Mellon's "Chemical Publications," have been used constantly and others have been consulted frequently. Permission was obtained from the Library of Congress to use the "unit card" shown in the second chapter, from the *Journal of Chemical Education* and Professor M. G. Mellon to use Table 26, which has been brought down to date. Without aid from various librarians I would have been unable to obtain some of the material on patents, particularly Table 47. To Miss Alice Harrison of our own staff I am especially indebted for hearty coop-

A number of technical problems have arisen during the compilation of this text. Recognized authorities have been followed whenever available. In other cases I have tried to adhere to one alternative for the sake of uniformity. The title page, for example, is assumed to be the official source of information about a book. I have so considered it, in spite of the fact that in some instances the publisher specified is no longer in business. Although this may inconvenience a prospective buyer, I feel that information regarding the present source of supply can be obtained readily from the various catalogs or any good book dealer.

In the text many words will be found with their first letter underlined. The purpose of this special marking is to indicate the word under which a searcher must look in catalogs or indexes for the material being discussed, e.g., government publications about British patents will be found under Great Britain in all library catalogs arranged according to accepted rules.

If in any particular case my choice of subject matter appears unwise, if I have omitted anything deemed essential, or if errors are found, I trust that the reader will feel sufficiently friendly to inform me and thus help to improve future editions, for only with such aid can I hope to make this book of maximum usefulness to all chemists.

B. A. Soule.

Ann Arbor, Michigan,
January, 1938.

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MELLON, M. G., "Chemical Publications," McGraw-Hill Book Co., New York, 1928.

SPARKS, M. E., "Chemical Literature and Its Use," published privately, Urbana, Ill., 1921.

MASON, F. A., "The Literature of Chemistry," Oxford University Press, New York, 1925.

REID, E. E., "Introduction to Organic Research," D. Van Nostrand Co., 1924.

BARROWS, F. E., *Chem. Met. Eng.*, **24,** 423, 477, 517 (1921). Investigations of the Chemical Literature.

HIBBERT, H., *ibid.*, **20,** 578 (1919). The Art of Searching Chemical Literature.

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LIBRARY GUIDE FOR THE CHEMIST

THE ARRANGEMENT OF A LIBRARY

"The first great principle in learning to use a library is to acquire the knack of saving time." W.W. BISHOP

A library is a storehouse for printed information. It is also a public utility attempting to provide its varied clientele with such intellectual fare as may be desired. The two functions give rise to certain major problems. First, how can books be stored so that each one will be readily available when needed? Second, what record or inventory should be kept of the volumes and their contents? Third, how are the possible solutions for each problem restricted by the patrons' needs and capabilities? Answers have been formulated and procedures developed during many years devoted to the consideration of all readers, not any one group or class. Furthermore, some of the rules formulated by librarians have been adopted by indexers and others who prepare the keys to literature. Consequently, only to the extent that the chemist understands current practice will he be able to use a library effectively and expeditiously. The following brief explanation will suffice for ordinary work. Details will be found in the various books mentioned at the end of this chapter.

CLASSIFICATION

Possibly the simplest way to take care of books would be to pile them up as received. Another method slightly more laborious would be to arrange them on shelves according to author, title, or publisher. None of these procedures is entirely satisfactory because too many people go to a library for informa-

tion about a topic. Only advanced students familiar with reference books would raise a question such as "What does Stoughton say about the melting point of iron?" or "How did Fischer prepare osazones?" In other words inquisitive people who turn to a library for help seldom know the author, title, or publisher of the book that will answer their questions. Because of this situation librarians have grouped books according to content, i.e., brought together on the shelves all material dealing with the same subject. Furthermore, related subject matter has been placed near by, thus suggesting additional sources of information. This process is called "classification."

Dewey Decimal system

Practically all librarians in the United States and many in other countries arrange books according to a system called the "Dewey Decimal" classification. This divides all literature into ten classes, each class into ten divisions, each division into ten sections, and each section into ten subsections (Table 1). When needed, additional subdivisions are used. Wherever the system has been adopted a new book may be assigned readily[1] to its class, division, etc., and placed with other material on the same subject. Obviously in order to do this someone must read enough of the book to ascertain its nature, then mark it in a way that will reveal its content and insure correct placement on the shelf not only the first time but also whenever subsequently removed. This could be done for a certain book by pasting on the cover a statement such as "This is a book on natural science. It deals with chemistry, especially the microscopic identification of inorganic compounds." The chemist, wedded as he is to the use of a few symbols for the purpose of conveying much information, will immediately appreciate the scheme adopted by Dewey for accomplishing the same objective.

Dewey arbitrarily selected ten classes so he could assign a digit to each. He did the same for the divisions and sections. He then ruled that the figure denoting a class should occupy the hundreds place, that representing a division the tens place, and a section the units place. If needed, a more detailed classification would be shown by means of decimals, *e.g.*, a digit in tenths

[1] This discussion is too cursory to consider the difficulties of classifiers.

TABLE 1.—OUTLINE OF DEWEY DECIMAL CLASSIFICATION

Classes	Divisions of Class 5	Sections of Division 4	Subsections of Section 4
0 General Works			
1 Philosophy			
2 Religion	0 Natural Science General	0 Chemistry (in general)	
	1 Mathematics	1 Theoretical	
3 Sociology	2 Astronomy	2 Practical and experimental	.1 Wet methods
		3 Analysis	.2 Dry methods
4 Philology	3 Physics	4 Qualitative.	.4 Gas analysis
5 Natural Science	4 Chemistry	5 Quantitative	.6 Spectrum analysis
	5 Geology	6 Inorganic	.8 Microscopic examinations
6 Useful Arts	6 Paleontology	7 Organic	
7 Fine Arts	7 Biology	8 Crystallography	
	8 Botany	9 Mineralogy	
8 Literature	9 Zoology		
9 History			

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5 Natural Science	3 Physics	3 Analysis	.2 Dry methods
6 Useful Arts	4 Chemistry	4 Qualitative..........	.4 Gas analysis
7 Fine Arts	5 Geology	5 Quantitative	.6 Spectrum analysis
8 Literature	6 Paleontology	6 Inorganic	.8 Microscopic examinations
9 History	7 Biology	7 Organic	
	8 Botany	8 Crystallography	
	9 Zoology	9 Mineralogy	

TABLE 2.—SOME DEWEY DECIMAL NUMBERS AND THEIR SIGNIFICANCE

A. Pure Chemistry (Abridged)

540	Chemistry (Pure, Chemical Technology is 660)
.3	Dictionaries
.5	Periodicals
541	Theoretical and physical chemistry
.2	Atomic theory
.3	Physical chemistry
.35	Photochemistry
.36	Thermochemistry
.37	Electrochemistry
542	Experimentation
.1	Laboratories
.2	Apparatus and manipulation
.3	Measuring apparatus
.4	Heating Distillation
.7	Gas manipulation cf. 544.4, 545.7
543	Analysis General works covering both qualitative and quantitative analysis
.1	Analysis of food and drink
.4	Analysis of drugs and medicine
.6	Analysis of rocks and ores
.7	Analysis of inorganic products in general
.8	Analysis of organic products in general
544	Qualitative analysis
.1	Wet methods
11	Reagents
.12	Detection of cations
544.13	Detection of anions
.4	Gas analysis
.6	Spectrum analysis cf. 535.84
.8	Microscopic examination
545	Quantitative analysis
.1	Gravimetric
.2	Volumetric
.3	Electrometric
.8	Other methods Colorimetric Polarimetric Refractometric
546	Inorganic chemistry
.1	Non-metals
.12	Halogen group
.13	Chlorine
.14	Bromine
.2	Oxygen group
.3	Metals
.31	Alkali group
.4	Alkaline earths
.6	Rare earths
.7	Iron group
547	Organic chemistry
.2	Hydrocarbons Aliphatic
.21	Paraffins
.25	Aromatics
.26	Benzene
.3	Alcohols Phenols (subdivided like 547.2)
.5	Aldehydes
.6	Ketones
.7	Acids Acid anhydrides
.8	Nitro derivatives
.9	Compounds with metals

B. Related Subjects

016.54	Bibliography of chemistry
026.54	Chemistry libraries
310	Statistics
371.66	Scientific apparatus Laboratory equipment and supplies
389	Weights and measures
500	Pure science in general
510	Mathematics
530	Physics
532	Liquids
533	Gases
535	Light Optics
.84	Spectroscopes and spectrum analysis
.85	Photography cf. 770
536	Heat
537.85	Electro-metallurgy
550	Geology
551.94	Geochemistry
552.8	Microscopic petrography
553.1	Ore deposits
.3	Ores of iron
.4	Ores of metals other than iron
.6	Earthy economic minerals
.7	Mineral waters
577.1	Properties of living matter, chemical
578	Microscopy
581.192	Chemical composition of plants
600	Useful arts Applied science
605	Periodicals
608	Patents Inventions
612.015	Physiological chemistry
.12	Chemical properties of blood
614	Public health
614.341	Fermented beverages
.35	Inspection of drugs
.355	Poisonous cosmetics
.37	Inspection of pigments, wall- and other papers, textiles
.484	Chemical disinfectants
.72	Air pollution by noxious gases
.831	Manufacture and storage of explosives and combustibles
.845	Chemical fire extinguishers
615	Materia medica and therapeutics
.7	Medicines grouped by effects
.9	Toxicology
616.076	Pathological chemistry Urine analysis
628.5	Industrial sanitation
630.24	Agricultural chemistry
631.8	Fertilizers
633.8	Perfumes
634.986	Saps
.9862	Naval stores
637	Dairy and dairy products
641.1	Food chemically considered
660	Chemical technology
669	Metallurgy and assaying
691	Materials Preservative processes
.7	Anti-rust processes
751	Painting materials and methods
770	Photography

place referring to a subsection.[1] In this way he used the possible three figure combinations to represent nine hundred ninety-nine subjects. Adding the first decimal place increased the number by nine thousand. The next place gives ninety thousand more, an ample number for any library of average size.

With reference to the example cited it is now obvious from Table 1 that the subject "microscopic identification of inorganic compounds" can be indicated by the Dewey Decimal notation, the code number being 544.8, obtained as follows:

Class	Natural Science	5––.–
Division	Chemistry	4–.–
Section	Qualitative Analysis	4.–
Subsection	Microscopic Examination	.8
	Summary	544.8

This number placed on a copy of Chamot and Mason's "Elementary Chemical Microscopy" would completely classify the book, indicating its contents and location on the shelf, i.e., beyond all books bearing a lower and ahead of all carrying a higher number (cf. Cutter number).

The system is in use for journal articles as well as books (see Chemisch Weekblad). It is also readily adaptable to personal notes (cf. p. 275). Everyone active in research work soon accumulates many data and references to the literature of his field. If they are to be available when wanted, the various items must be arranged in some order. As soon as this stage is reached the worker should carefully consider the well-constructed keys already available before attempting to devise a new one for himself. Depending upon the extent of the subject matter included the entire Dewey system might be used, or a small part of the outline, such as that on chemistry, could be expanded to meet his needs. A study of the scheme from 621.384 to 621.385 will show how this has been done to take care of every detail in the literature on radio communication and apparatus. The plan given is possibly too detailed for ordinary use, but it serves to illustrate the potentialities of the system. Incidentally the Dewey "Relativ Index" should be very useful in any case.

[1] The decimal point is used for the same purpose as a comma in ordinary numbers: to aid the eye in reading.

It is an alphabetical arrangement of subject headings giving the assigned Dewey Decimal numbers and cross references to related headings under which relevant information might be filed.

Brussels system

The system used by the Brussels Institute for classifying the literature of the world in the minutest manner is essentially the Dewey arrangement carried one or more decimal places further to provide at least a million additional subdivisions. It is especially valuable to research workers as a basis for assembling a bibliography without setting up their own modifications.

Library of Congress system

The Library of Congress system was devised solely for the Congressional Library at Washington, hence is especially developed along the lines of United States history, government, and geography. Although the scheme is still unfinished, about twenty classes (see Table 3) have been established and more or less completely developed. The symbols used are primarily the letters of the alphabet which represent classes. A second letter indicates a particular division within each class (see Table 3 B). Further sectioning is obtained by resorting to numbers, four figures being the maximum employed at present. To revert to the example used on p. 6, Chamot and Mason's book would carry the "L.C." code number QH 221.[1]

Cutter numbers

If a library has more than one book on a particular subject all will bear the same classification number, but all cannot occupy the same space on the library shelf. Consequently a precedence indicator[2] is used. It is called a "Cutter" or "author number" and is based upon the author's name. The first part is the first letter of the author's name. This is followed by a

[1] Microscopy is here classed as a special subdivision of Natural History. The writer believes that a more logical number would be QD 88, since blanks have been left between QD 87 and QD 95 apparently for special phases of qualitative analysis.

[2] For a detailed discussion of "book numbers" see Miss Mann's book referred to on p. 23.

TABLE 3.—SOME LIBRARY OF CONGRESS NUMBERS AND THEIR SIGNIFICANCE

A. Classes in the L.C. System

A	General works—Polygraphy	L	Education
B	Philosophy—Religion	M	Music
C	History—Auxiliary Sciences	N	Fine Arts
D	History and Topography (except America)	P	Language and Literature
E–F	America	Q	Science
G	Geography—Anthropology	R	Medicine
H	Social Sciences	S	Agriculture
J	Political Science	T	Technology
K	Law	U	Military Science
		V	Naval Science
		Z	Bibliography and Library Science

B. Divisions of Class Q, Science

Q	Science (general)	QH	Natural History
QA	Mathematics	QK	Botany
QB	Astronomy	QL	Zoology
QC	Physics	QM	Human Anatomy
QD	Chemistry	QP	Physiology
QE	Geology	QR	Bacteriology

C. Pure Chemistry, Class QD (Abridged)

QD	1	Periodicals
	4	Encyclopedias
	5	Dictionaries
	11	History (general)
	21	Biography of chemists, collective
	22	Biography of chemists, individual
	61	Laboratory technique (general)
	75	Analytical chemistry (general works)
	81	Qualitative analysis (treatises)
	101	Quantitative analysis
	111	Volumetric analysis
	115	Electrolytic analysis
	121	Gas analysis
	131	Technical analysis
	151	Inorganic chemistry (treatises)
	161	Non-metals
	171	Metals (general)
	181	Metals (special topics)
	251	Organic chemistry (treatises)
	258	Operations in organic chemistry
	261	Laboratory manuals
	262	Organic synthesis
	271	Organic analysis
	301	Fatty compounds (aliphatics in general)
	305	Special groups (alphabetically)
	331	Aromatic compounds (general)
	341	Special groups (alphabetically)
	453	Physical and theoretical chemistry (general)
	511	Thermo-chemistry
	541	Theory of solution (general)
	553	Electro-chemistry
	601	Photo-chemistry
	905	Crystallography
	931	Physical properties of crystals
	951	Chemical crystallography

D. Related Subjects

BF	1630–9	Alchemy
CT	9440	Biography of chemists
GC	101	Sea water—Physical and chemical properties
HA		Statistics
LB	1648	Chemistry in high schools
	2365	Higher education—Special subjects
QA		Mathematics
QB	875	Stellar spectroscopy
QC		Physics
	171–220	Constitution and properties of matter
	252–338	Heat
	451–495	Spectroscopy
QE	351–399	Mineralogy
QH	201–277	Microscopy
QK	861–899	Chemical botany
QP	501–801	Physiological chemistry
RA		State medicine Hygiene
	430	Sanitary chemistry
	576–578	Air pollution
	602	Foods
	766	Special disinfectants
	778	Cosmetics
	1195–1228	Toxicology
	1230–1231	Inorganic poisons
	1235–1242	Organic poisons
RB		Pathology
	37	Laboratory methods
	40	Chemical examination
RS	403–431	Medical and pharmaceutical chemistry
S	583–588	Agricultural chemistry
T	201–379	Patents
TD	380–387	Examination and analysis of water
TN	380	General mining and smelting companies
	400–409	Iron mining
	600–799	Metallurgy
TP		Chemical technology
TR		Photography
TS		Manufactures
UF	860	Military explosives and pyrotechnics
UG	447	Chemical warfare: gas and flame
Z	5521–5526	Subject bibliography Chemistry

number, the latter assigned by reference to "Cutter's Alfabetic-order Table." A sample of this work is shown in Table 4. Using this portion to illustrate the system, assume that Daborn,

Faber, and Feldner have each written a book on organic dyes. The three books will carry the same classification number, but the Cutter numbers will be D115, F115, and F312, respectively, and the volumes will be shelved in the order of these numbers.

TABLE 4.—A PORTION OF CUTTER'S ALFABETIC-ORDER TABLE

Da	111	Fa	Dao	211	Fane	Dee	311	Feit
Dabi	112	Fab	Dap	212	Fani	Deer	312	Feld
Dabl	113	Fabb	Dar	213	Fann	Def	313	Feli
Dabn	114	Fabe	Darc	214	Fano	Defo	314	Felic
Dabo	115	Faber	Dard	215	Fans	Defor	315	Felin
Dabr	116	Faberi	Darde	216	Fant	Defr	316	Felix
Dac	117	Fabert	Dare	217	Fanto	Deg	317	Fell
Daci	118	Fabi	Dari	218	Fantu	Degl	318	Felle
Dacr	119	Fabil	Dark	219	Far	Dego	319	Felli

Call numbers

A call number consists of two parts: the classification number and the Cutter number. The functions of the call number are to reveal the subject of the book, to show where it should be placed on the shelves, to act as a connecting link from the description in the catalog to the book in the stacks, and to aid in replacing the volume whenever removed from the shelf.

Shelf list

In all up-to-date libraries an inventory is kept of the books on hand. This record is technically called a "shelf list." It usually consists of a set of cards arranged exactly in the order of the books on the shelves. Each card shows the call number, author, and title of the book that it represents. In addition, following each card listing a periodical or set of books issued serially, there is a "holdings card" showing the volumes or issues of that series available.

References

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DEWEY, MELVIL, "Decimal Classification and Relativ Index," Forest Press, Lake Placid Club, N.Y., 1932. Thirteenth (memorial) edition revised and enlarged by Dorkas Fellows, editor; Myron W. Getchell, associate editor.

"Classification décimale universelle," Institut International de Bibliographie, Brussels, 4 vol., 1927–34.

U.S. Library of Congress, "Classification, Outline Scheme," "Class Q, Science," "Class T, Technology," Government Printing Office, Washington. Other books in this group are available, but these three are considered the most important for chemists.

THE CARD CATALOG

> *"For most inquiries reaching beyond the stage of the merely obvious, it [the card catalog] is a most complicated instrument requiring great skill and long practice in the searcher. . . . Catalogs are complex because people and books are complex."* W.W. Bishop

After a book has been classified and shelved, the librarian faces the problem of erecting adequate signposts directing the inquirer to a desired volume or, more often, to a particular item of information. If the guides mention only authors, they may be of little help. If titles alone are used they frequently will be valueless or positively misleading. Who, unfamiliar with the book, can tell the nature of Chapin's "Second Year College Chemistry"?—Satisfactory pilots must be available, therefore, to steer the searcher directly to the book containing desired information on the topic being investigated and to suggest other pertinent sources. This is the primary purpose of the card catalog. It may possess many other features, but essentially it is a directory, a divining rod for the location of information. Viewed as a tool the usefulness of a catalog depends upon two factors: the quality of its construction and the skill of the searcher. In order to determine the former one must have some notion of the raw materials and guiding principles involved. These are briefly discussed in this chapter. The proficiency of the operator depends upon his understanding of the complexity of the catalog and his practical experience in its use.

CATALOG CARDS

Data on cards

The card catalog, as its name implies, is a card index. It contains at least two, usually three or more, cards for every book in the library. These cards are placed in different parts

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of the collection as a result of its alphabetical arrangement, but all carry essentially the same data as indicated in Fig. 1.

Technically the items on a card are divided into six groups as follows:

1. Call number....... Inserted by the local library. Note the L.C. and Dewey Decimal suggestions of the Library of Congress printed at the bottom. This tends to impart uniformity in libraries using L.C. cards
2. Author........... His real name in full with birth and death dates. The latter serve as the best means of identification
3. Title.............. In full as it appears on the title page. In addition the author's name and the edition are included
4. Imprint.......... The publisher's name, address, and date of publication

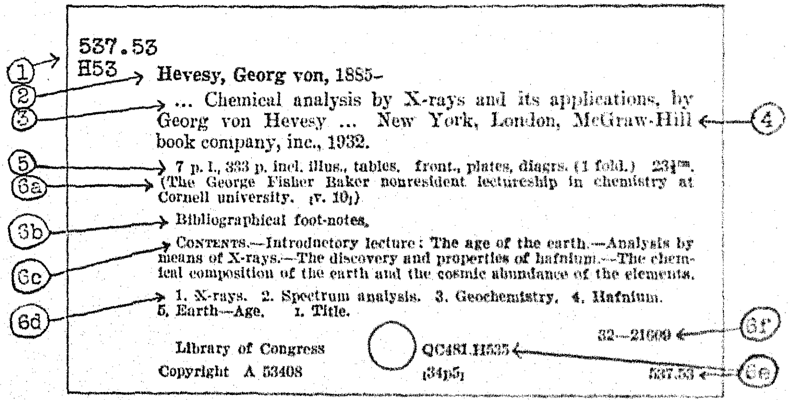

FIG. 1.—An author or main entry card prepared from an L.C. "unit" card.

5. Collation......... The data specifying the volumes, pages, illustrations, plates, maps, and other material constituting the book
6. Notes.......... (*a*) These mention the series title if the book is one of a series, (*b*) call attention to any bibliographical data, (*c*) give the contents briefly or so detailed that every chapter or subject is listed, (*d*) indicate other headings under which the book should be entered, (*e*) suggest classification numbers, (*f*) state the L.C. order number for the card

Usually cards carry the first four divisions complete if these data are available; the sixth section may be entirely lacking. It is to be expected, of course, that practice will vary in different

libraries. Considerable uniformity, however, is being attained nowadays through the use of the L.C. printed cards.[1]

Kinds of cards

As stated on p. 13, two or more copies of each catalog card are entered for every book possessed. An *author*, or main entry, card is filed under the author's real name (Fig. 1 illustrates an author card). A *subject* card is placed under the subject heading that most precisely describes the content of the book;[2]

537.53 X-rays
H53
Hevesy, Georg von, 1885–
... Chemical analysis by X-rays and its applications, by Georg von Hevesy ... New York, London, McGraw-Hill book company, inc., 1932.

FIG. 2.—Upper part of a subject card. The subject is typed in red or black.

e.g., Fig. 2 shows the top of the subject card for Hevesy's "Chemical Analysis by X-rays. . . ." There might also be cards under the headings listed in 6*d* of Fig. 1. A *title* card[3] is entered under the first significant word of the title not an article (see Fig. 3). In addition to author, subject, and title entries the catalog will contain *series* and *reference* cards (the latter are

[1] Two copies of every book granted a United States copyright are deposited in the Library of Congress. Catalog cards for all books acquired are prepared and printed for use in that library. Anyone desiring copies of such cards may purchase them for a nominal sum. In addition to this service the Card Division will assemble and sell "all cards" on a particular subject. Also, arrangements can be made whereby the cards in a special field, printed during the month, will be sent to a subscriber at the end of that period. For example, if the preparation of a bibliography on organic chemistry is contemplated the Card Division will furnish all cards thus far accumulated and keep the collection up to date by monthly additions. For further details see the references at the end of this chapter.

[2] The librarian and chemist may not agree on this point. Cross reference cards are placed in the catalog to help the chemist ascertain the librarian's decision, e.g., frequently works on ceramics, keramics, and porcelain are all entered under "Pottery."

[3] The present tendency is to omit title cards especially when the title is not distinctive or descriptive.

frequently called "see" and "see also" cards). These five groups, plus the necessary guide cards, comprise the directory to a library which theoretically makes it possible for anyone to find any information desired if either the author, title, or subject is known. Practically, however, many difficulties arise because no librarian can anticipate the needs of every patron and no ordinary catalog can contain a reference to every item of information in each book possessed. Realizing the situation, catalogers have adopted certain rules of practice, an understanding of which will often help one to find a particular book in a minimum

537.53	Chemical analysis by x-rays
H53	**Hevesy, Georg von, 1885–**
	... Chemical analysis by X-rays and its applications, by Georg von Hevesy ... New York, London, McGraw-Hill book company, inc., 1932.

FIG. 3.—Upper part of a title card. The typed title is in black.

of time. These rules, compiled by committees of the American Library Association, The (British) Library Association, and others eminent in the library world, attempt to answer such questions as, Who shall be considered an author? How shall cards be arranged? Etc. A brief summary follows.

Authors

In the catalog all of the following are considered authors, and a card will be found entered under each appropriate name: the author, a joint author, the editor, the compiler, a corporate body. Whenever two or more persons have collaborated in writing a book the one whose name appears first on the title page is termed the "author," "main author," or "senior author"; all others are called "joint authors." A card is placed in the catalog under each name, joint authors being so designated. When the work of three or more authors has been guided and supplemented by another he is called the "editor," and the resulting book is entered under his name (Taylor's "Treatise on

Physical Chemistry"). If the work is "analyzed"[1] a card will be found under the name of each individual author and each subject. Certain periodicals have "added entries" under the name of the editor as well as the official title (Silliman's "Journal of Science," Crookes' "Chemical News"). Cyclopedias and dictionaries are entered under the editor's name unless decidedly better known by their titles (Thorpe's "Dictionary of Applied Chemistry"). On the other hand, a series is entered under its title unless universally known by the name of the editor or publisher. Festschriften and similar collections published by a society or institution in honor of a person or celebrating an anniversary are usually found under the name of the society or institution with an additional card under the title. They may also be entered under the word Festschrift.

A compiler is one who gathers and arranges the work of others (Landolt-Börnstein's "Physikalisch-chemische Tabellen"). Unless it has become essentially a new book, a translation or a revision is entered under the name of the original author with an additional card under the name of the translator or reviser (Daniel's revision of Getman's "Outline of Theoretical Chemistry"). Societies, institutions, and certain other organizations are included in the term "corporate body" and as such they are considered to be authors of their official publications. The main entry for a journal published by a society is under the first word, not an article, of its corporate name (Journal of the American Chemical Society; The London, Edinburgh and Dublin Philosophical Magazine and Journal of Science). There may also be a card under the name of the place where the society's headquarters are established.[2] The main entry for a government publication is under the name of the country. Great

[1] A technical term used to indicate that entries have been made for parts of the book; e.g., there is a separate card for each essay in Thorpe's "Essays on Historical Chemistry."

[2] The problem of where to look in the catalog for the card referring to a chemical journal often may be solved by first getting the correct title from the "List of Periodicals" abstracted by Chemical Abstracts. The latest edition was published in November, 1936.

Britain would be the proper heading under which to look for material on British patents. United States Bureau of Standards is the main entry for all official publications of that bureau. Another card may be entered under the actual author of a sufficiently important bulletin.

Subjects

A card catalog is, in one sense, a subject index to the information in a library. How detailed the index should be depends primarily upon the function of the library. For a special reference collection used chiefly by experts whose time is valuable, the catalog might well contain a card for each item of subject matter in every book of the assemblage. If, for example, a chemist is interested in the iodometric determination of arsenic he should expect to find in the specialized catalog, under one heading, a reference to every discussion of the subject in the library, and there should be enough cross-reference cards to guide him directly to that heading from any reasonable expression of the idea that he might put into words. Furthermore, the subject headings should be in the technical terms common to his special field.

The other extreme, perhaps, might be represented by the average public library having about a dozen books on chemistry. There the catalog should contain only one subject entry: Chemistry—with few if any cross reference cards, because any patron of that library would be interested only in the broader aspects of the subject. His needs would be amply served by the one entry.

Somewhere between special reference and general public libraries is that of the university catering both to research workers and to students just starting academic work. This wide diversity of interest makes doubly difficult the task of selecting subject entries that will be suitable for the general catalog and at the same time useful in a specialized departmental library. It necessarily shifts to the shoulders of the specialist the responsibility for carrying his ideas back from their specific phrasing to the general terms selected by the cataloger. Because this type of catalog is the one most frequently used by the chemist a few of the guiding principles in the selection of subject headings should be understood.

The determination of arsenic by use of standardized iodine is obviously a specific application of iodometry which, in turn, is a part of volumetric analysis. This belongs to the field of analytical chemistry. Arrangement in reverse order gives:

Chemistry
  Analytical chemistry
    Quantitative analysis
      Volumetric analysis
        Iodometry
          Determination of As

In the type of library under consideration the cataloger has at least two choices: entry under the main heading or entry under a subheading, e.g., the fourth, assuming that anyone desiring data on iodometric methods should know that they might be found in a book on volumetric analysis. A card catalog, however, is arranged strictly alphabetically. Hence, considering the first three headings as they stand, "Chemistry" would be filed under C, "Analytical chemistry" under A, and "quantitative analysis" under Q. Inverting the second and third headings gives a series that will alphabet under the main subject:

Chemistry
  Chemistry, Analytic
    Chemistry, Analytic—Quantitative

Such an expedient brings together all cards on every phase of chemistry. If the library has a number of books on a particular subtopic the cataloger will probably enter them directly under that heading and not under the main heading. Consequently when the catalog is being used to locate information on the iodometric determination of arsenic either of two procedures may be adopted: (*a*) Start with the most specific heading (Iodometry) and work up to the more general, or (*b*) first find the guide card "Chemistry," then beyond that "Chemistry, Analytic," and so on down to the most specific one in the catalog that covers the desired subject. Synonymous terms and variations in word order must also be considered.

Although many other cases can be handled in a similar way, it must not be inferred that inversion is always employed. Books on electrochemistry are filed under the letter E, the heading

"Gastric Juice" appears under G, etc. Certain other points are also worth noting, among them the following:

a. One of the primary objectives is to catalog a book under whatever heading it may reasonably be sought, but because of cost and other factors the librarians consider it impractical to enter many subject cards for one book.

b. Analytics in a large library will usually be limited to monographs in a series. Note that this does not apply to the highly specialized reference library where frequently two or three hundred cards are entered for a single volume.

c. A subject heading must fit the individual book, but the word or phrase used must stand for a subject, not for one book.

d. Headings are subdivided by subject (see arsenic example) and by form, e.g., "Chemistry, Dictionaries" not "Dictionaries, Chemistry." Subjects may be subdivided geographically, e.g., "Dyes and Dyeing, France."

e. Common terms are preferred. Of the synonyms "Poisons" and "Toxicology" the former would be used.

f. Combined terms are used when the subjects are so closely related that they are ordinarily discussed together ("Dyes and Dyeing").

g. Suitable "see" and "see also" cards will be found in appropriate places, but as a general rule the searcher is not referred from a smaller to a larger subject; e.g., probably no reference card will be found from "Volumetric analysis" to "Chemistry, Analytic."

Finally, the searcher must approach the catalog knowing what he wants to find and having his idea expressed in the words used by the cataloger. The catalog is complex because books are complex not because the librarian wants to conceal them.

Arrangement of cards

The order of cards in a dictionary catalog is strictly alphabetical.[1] This rule causes no confusion when applied to subject cards unless one ignores the likelihood of inversion. In the latter case a cross reference will usually solve the problem.

[1] This will vary slightly in different libraries depending on the local practice when a word can be used to indicate a person, place, subject, form, or title. Other variations are also mentioned by Cutter (Bibliography, p. 23).

Title cards are filed under the first significant word not an article. Frequently the cataloger will ignore non-distinctive words at the beginning; e.g., "An Improved Victor-Meyer Apparatus" is shortened by omitting the first two words, but "The Structure of the Arc-spectrum of Zirconium" is decreased to "Arc-spectrum of Zirconium."

A careful distinction is made regarding a periodical. If it is the Journal (Berichte, Proceedings, Bulletin . . .) of a society or institution the entry is under the corporate name of that organization. When the title does not include a corporate name the entry is under the first word of the title excluding articles (see Table 5).

TABLE 5.—PERIODICAL CARDS DIFFICULT TO LOCATE IN THE LIBRARY CATALOG

NOTE.—The following journal titles are entered under the word italicized. Frequently the catalog will contain a "see" card from the name ordinarily used.

Annalen or Liebigs Annalen. *Justus* Liebigs Annalen . . .
Berichte der *Deutschen* chemischen Gesellschaft
British Chemical Abstracts
Bulletin de la *société* chimique de France
Chemisch Weekblad
Chemistry and Industry. *Society* of Chemical Industry
Comptes rendus. . . . *Académie* des sciences
Fortschritte der Chemie, Physik und physikalischen Chemie
Journal of the *American* Chemical Society
Journal of Chemical Education
Journal of the *Chemical* Society (London)
Journal of the *Franklin* Institute
Journal of the *Optical* Society of America
Journal of Physical Chemistry
Journal für praktische Chemie
Journal of the *Society* of Chemical Industry
Philosophical Magazine. *London*, Edinburgh and Dublin . . .
Proceedings of the *Royal* Society (London)
Recueil des travaux chimiques des Pays-Bas
The *Review* of Scientific Instruments
Transactions of the (American) *Electrochemical* Society
Transactions of the *Faraday* Society
Transactions of the *Royal* Society (London)
Zeitschrift für analytische Chemie
Zeitschrift für physiologische Chemie. *Hoppe-Seyler*

Author and joint author cards may be considered in four groups: (1) names that obviously can be filed in but one place,

(2) English names the order of which must be decided arbitrarily, (3) foreign names involving prefixes, and (4) foreign names requiring transliteration.

The first division needs no further consideration. The second includes:

a. Names beginning with M', Mc, or Mac all of which are arranged as if written Mac.

b. Names beginning with St. or Ste. are arranged as if spelled out.

c. English surnames having prefixes are arranged under the prefix regardless of the derivation of the name (De Land, Van Buren).

d. Entries involving titled persons are filed under the title (Lord Kelvin, not William Thompson).

e. Cards for married women are arranged under the latest name or that better known (Marie Curie, Pauline Beery Mack).

Foreign names involving prefixes are slightly troublesome. French and Belgian surnames are filed under the prefix when it is, or contains, an article (La, Le, L', Du, Des); under the word following, when the prefix is a preposition (de, d'). For all other foreign languages the names are filed under the word following the prefix (van Rijn, von Wiemarn, but cf. Von Oettingen). German names containing umlauted letters (ä, ö, ü) and Danish names containing ø are arranged as though an e followed the marked letter (Böttger precedes Bofert; Brønsted precedes Brogley).

Russian and other names that must undergo transliteration are arranged under the "most familiar" form. This often causes uncertainty, especially when the German form has been widely used and an English version is also popular (Tschugaeff vs. Chugaev; Mendelyeev, Mendelieff, Mendelev, Mendelejeff, Mendeljeff, and Mendeleef have all been used to designate the Russian scientist famous for his periodic table).

The problem of locating personal names is not confined to the library catalog, for, as previously stated, the catalog is but one form of an index. Hence, whenever any author index is to be consulted its arrangement should be studied. One should hesitate to say that a name has not been entered until every possible

place has been searched; the spelling, and even the name itself, verified.

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AMERICAN LIBRARY ASSOCIATION AND THE (BRITISH) LIBRARY ASSOCIATION, "Catalog Rules, Author and Title Entries," American Library Association, Chicago, 1908.

CUTTER, C.A., "Rules for a Dictionary Catalog," U.S. Government Printing Office, Washington, 4th ed., rewritten, 1904.

PIERSON, HARRIET W., "Guide to the Cataloging of the Serial Publications of Societies and Institutions," U.S. Government Printing Office, Washington, 2d ed., 1931.

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BIOGRAPHY

When asked how he had done so much in his short life, Abel [eminent mathematician, 1802–1829] replied, "By studying the masters not the pupils." E.T. Bell

Chemical literature is the record of man's achievements—his positive results and theories. Since the product is limited by the capacity of the producer to conduct dependable experiments and draw rational conclusions, it behooves those who would make use of previous findings to become acquainted with the masters and their methods. Almost any good book on the history of chemistry will serve as a starting point. Perhaps some of the collective biographies might furnish more details but would not be so satisfactory for perspective. After a general notion of the various movements and their exponents has been acquired, biographies of the individuals identified with a particular field of interest might next be considered. Finally, the adepts of today should not be neglected.

Sources of information to be consulted will depend upon the nature of the question. Historical background can be obtained from Meyer, Moore-Hall, or Venable (see p. 26). Collections of biographies range all the way from Michaud's "Biographie Universelle" to the popular one-volume "Who's Who" of today. Individual biographies appear in book form and scattered through the periodical literature. It is obvious, therefore, that a search for data concerning any scientist may be short or long depending upon the individual and the details required. Generally the task is simplified if dates of birth and death are known, because biographical sources may be divided into two groups: those dealing only with dead people and those considering living or recently deceased persons. Given also the nationality and eminence of a man, the direction of the search is very definitely indicated. With nothing but the name, and that possibly incorrect, the first step may well be to consult the card catalog. If a biography is found it may prove adequate or give references

to other information. Should an author entry[1] be discovered it will probably furnish the author's dates and the year in which the book was published. If nothing is found the order of subsequent steps might be to consult:

a. Poggendorff (see p. 28 for detailed reference).
b. Various dictionaries of national biography.
c. Bolton's "Select Bibliography" (Section 4).
d. "American Men of Science."
e. "Minerva" or "Index Generalis."
f. "Europa."
g. "Who's Who" for individual countries.
h. Membership lists of the various chemical societies.

At best, data regarding a living chemist will be meager unless the man has held an important position or been the recipient of a well-known prize. In difficult cases it may be necessary to search the various journals using such headings as Biography, Obituary, Necrology, or the proper equivalent in other languages. Additional suggestions will be found in the following section.

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VENABLE, F.P., "A Short History of Chemistry," D.C. Heath & Co., Boston, 2d ed., 1922. Very brief.

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Vol. I. Zosimus to Schönbein.
Vol. II. Liebig to Arrhenius.

CHEMICAL SOCIETY (London), "Memorial Lectures," Gurney and Jackson, London.

[1] A "Depository Catalog" is of greater service in this respect, because an effort is made to include all authors whether or not the local library has a book by the person in question.

Vol. I. 1893–1900.

Bunsen	Kekule	Meyer, V.
Friedel	Kopp	Nilson
Helmholtz	Marignac	Pasteur
Hofmann	Meyer, L.	Stas

Vol. II. 1901–1913.

Becquerel	Gibbs, Wolcott	Moissan
Berthelot	van't Hoff	Rammelsberg
Cannizzaro	Ladenburg	Raoult
Cleve	Mendelieff	Thomsen
	Wislecinus	

Vol. III. 1914–1932.

Arrhenius	Fischer, E.	Richards
Baeyer	Onnes	van der Waals
	Wallach	

HARROW, "Eminent Chemists of Our Time," D. Van Nostrand Co., New York, 2d ed., 1927.

Arrhenius	Mendelieff	Ramsay
Curie, Marie S.	Moissan	Remsen
Fischer, E.	Meyer, V.	Richards
van't Hoff	Perkin	

HOLMYARD, "The Great Chemists," Methuen & Co., London, 3d ed., 1929.

Arrhenius	Davy	Mendelieff
Avogadro	Jabir	Paracelsus
Bacon	Kekulé	Pasteur
Boyle	Lavoisier	Priestley
Dalton	Liebig	Ramsay
	Stahl	

JAFFE, "Crucibles," Newton Publishing Co., New York, 3d printing, 1932.

Arrhenius	Curie, Mme.	Moseley
Avogadro	Dalton	Paracelsus
Becher	Langmuir, I.	Priestley
Berzelius	Lavoisier	Thompson
Cavendish	Mendelieff	Trevisan
	Wöhler	

LENARD (trans. by Hatfield), "Great Men of Science," The Macmillan Co., New York, 1933. These biographies vary in

length from less than one to over twenty pages. The chemists discussed include:

Berzelius	Dalton	Klaproth
Black	Davy	Priestley
Bunsen	Faraday	Rumford, Count
Cavendish	Gay-Lussac	Scheele
Crookes	Kelvin, Lord	

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Davy	Liebig	Mayer
Faraday	Gerhardt	

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Boyle	Faraday	Mendelieff
Cannizzaro	Graham	Meyer, V.
Cavendish	Kopp	Priestley
Dumas	Lavoisier	Scheele

TILDEN, "Famous Chemists, the Men and Their Work," G. Routledge and Sons, London, 1921.

Avogadro	Dalton	Liebig
Berzelius	Davy	Mendelieff
Black	Dumas	Priestley
Boyle	Faraday	Proust
Cannizzaro	Frankland	Ramsay
Cavendish	Gay-Lussac	Scheele
Crookes	Lavoisier	Williamson

POGGENDORFF, "Biographisch-literarisches Handwörterbuch . . . ," J.A. Barth, Leipzig, recent volumes by Verlag Chemie, Berlin.

Vol. I and II . . .	down to 1857
III . . .	1858–83
IV . . .	1884–1904
V . . .	1904–22
VI . . .	1923–31

This is one of the best sources for information about the life and work of scientists of all times and in all countries. The most important feature is the complete bibliography accompanying each biography (cf. Kurkula, p. 31).

OTTO, PAUL, "Technischer Literaturkalender," R. Oldenbourg, Munich, 3d ed., 1929. A dictionary of German scientists.

It includes brief biographies and bibliographies. There is a subject index arranged alphabetically according to fields of concentration.

"Minerva. Jahrbuch der gelehrten Welt," Walter de Gruyter Co., Berlin. Founded by Kurkula and Trübner (cf. Kurkula, p. 31), this work includes concise information about the universities, learned societies, museums, etc., of the world. The arrangement is alphabetical by name of town, giving under each the educational institutions located there together with data regarding size, name of each principal officer and staff member, publications, etc. There is an index of personal names. The book was published annually 1891–1914, thereafter irregularly (1926, 1928, 1930). In 1933 two divisions were established: (1) Universities, (2) Societies.

"Index Generalis," Éditions Spec, Paris, 17 Rue Soufflot, 1919– . Published under the direction of R. de Montessus de Ballore. The first part is devoted to data regarding universities and other schools of higher education all over the world. It gives their main departments and eminent professors. The second part lists the observatories, libraries, scientific institutes, national academies, and learned societies of the world. Frequently the text is in the language of the country concerned.

Bolton, H.C., "Select Bibliography of Chemistry," The Smithsonian Institution, Washington, 1893–1904. Section 4 on "Biography" covers the period 1492–1900. As the title indicates, a bibliography of biographical material is given, not the biographies themselves.

Who's Who's

There are two major groups: one dealing with people active in a limited field, e.g., scientists; the other concerned with all celebrities in a particular geographical area. Only a few of the latter are mentioned here.

Cattell and Cattell, "American Men of Science," Science Press, New York, 5th ed., 1933. (A revision is issued every 5 years.) There are about 22,000 biographies in this edition. Attention is directed to the starred names and the significance of the star as discussed in the appendix of this and earlier issues.

HAYNES (ed.), "Chemical Who's Who," The Haynes & George Co., New Haven, Conn., 1937. The first edition, published in 1931, was entitled "Who's Who in the Chemical and Drug Industries." Contains over 5500 biographies arranged alphabetically. It is indexed by companies and by cities. Anyone seeking an industrial position should have a copy of this book because it includes "all our chemical leaders—executives in offices, plants and laboratories, technicians, consultants and educators." Supplementary entries will be found in Chemical Industries, for 1937.

MIELI, "Gli Scienziati Italiani . . . ," Nordecchia, Rome, 1921–3. Has been somewhat slow in appearing.

MARQUIS, "Who's Who in America," A.N. Marquis Co., Chicago. Issued biennially, it contains biographical data and a bibliography in case of an author. "All people mentioned are selected by a competent committee."

"International Who's Who," Europa Publications, London, 1935. This book is intended to supplement, not replace, the various national forms of "Who's Who." Only a few chemists are included.

"Europa," Europa Publications, London, 1931– , Vol. II, Biography. This claims to be the most comprehensive work of the "Who's Who" type, covering continental Europe and the British Isles. It is revised and brought up to date every 2 months.

"Who's Who," The Macmillan Co., New York (American agency). Issued annually and covers British celebrities. It is the pioneer of the group and probably the most important member.

"Who Was Who," A. & C. Black, London, 1929. A companion to the British "Who's Who" containing the biographies of those who died between 1916 and 1928.

"Wer Ist's?" Herman Degener, Berlin. Published irregularly. It includes German, Austrian, and Swiss notables. The entries are thought by some people to be difficult to read because of the number of abbreviations. These are explained at the beginning. The arrangement should also be noted.

"Qui êtes vous?" Ruffy, Paris. Published annually since 1908.

"Chi È?" Stet, Rome, 2d ed., 1931.

"Blaa Bog," Kraks legat, Copenhagen, 1936.

General sources

THOMAS, "Universal Pronouncing Dictionary of Biography . . . ," J.B. Lippincott Co., Philadelphia, 5th ed., 1930. This book is usually called "Lippincott's Biographical Dictionary." It includes people of all nations and times.

HYAMSON, "Dictionary of Universal Biography of All Ages and of All Peoples," E.P. Dutton & Co., New York, 1916.

MICHAUD, "Biographie universelle," Mme. C. Desplaces, Paris, 1843–65, 45 vols. Although over 60 years old this is one of the most valuable of all large compilations. The title page gives its scope: "An alphabetical history of the public and private life of all men who were remarkable for their writing, action, talents, virtues, or crimes."

"Dictionary of American Biography," Charles Scribner's Sons, New York, 1928–36, 20 vols. A supplementary volume is to be issued every 10 years. There are over 13,500 biographies, but no living person is included.

STEPHEN and LEE (ed.), "Dictionary of National Biography," Smith Elder and Co., London, Vol. 63 published in 1900, 3d supplement issued during the period 1912–21. This is the best reference work for English biography in general. Living persons are not considered. There is an epitome of the set which was published in London by the Oxford University Press in 1930.

BALTEAU, RASTOUL and PREVOST (ed.), "Dictionnaire de biographie française," Letouzey, Paris, 1929– . A's unfinished in 1936. Promises to be very fine.

HISTORICAL COMMISSION OF THE IMPERIAL ACADEMY, "Allgemeine Deutsche Biographie," Duncker and Humblot, Leipzig, 1875–1912, 56 vols. Nachträge bring the period covered down to 1900. When using this source first consult the general index in Vol. 56.

KURKULA, "Allgemeine deutschen Hochschulen-Almanack," Vienna, 1888. Bibliographies of all living professors and teachers in German and Austrian universities and technical

schools. It forms, in part, a supplement to Poggendorff (cf. Minerva).

Prize winners

The various awards and lists of their recipients have been compiled by James A. Funkhouser and published in *Ind.Eng. Chem., News Ed.* **14,** 123–464 (1936). Specific page references are given in Table 6.

TABLE 6.—HONORARY AWARDS

Award	First bestowed	List of recipients*
A.A.A.S. Prize	1923–4	344
Acheson Medal	1929	416
A.C.S. Award	1931	430
Am.Inst.Chem.Medal	1926	416
Chandler Lecture	1914	280
Conné Medal	1933	448
Ebert Prize	1874	123
Franklin Medal	1915	302
Gibbs Medal	1911	250
Grasselli Medal	1920	330
Herty Medal	1933	464
Hillebrand Prize	1925	374
Mendel Medal	1929	430
Morehead Medal	1922	344
Nichols Medal	1903	201
Nobel Prize†	1901	182
Osborne Medal	1928	416
Perkin Medal	1906	226
Pittsburgh Award	1933	464
Priestley Medal	1923	374
Remington Medal	1919	330
Richards Medal	1930	430
Schoellkopf Medal	1931	448
Soc.Chem.Ind.Medal	1933	448

* The numbers in this column are page references to the lists published in *Ind.Eng.Chem., News Ed.*, **14** (1936).

† The official annual report of each year's activities is published under the title "Les prix Nobel en 19 ," P.A. Norstedt and Sons, Stockholm. It contains a biographical sketch of each recipient, his portrait and presentation speech, the latter comprising a summary of the work for which the prize was granted. (This set of books is entered, in some library card catalogs, under the word Nobelstiftelsen.)

Portraits

KILLEFFER, "Eminent American Chemists," D.H. Killeffer, New York, 1924. Contains portraits and brief notes.

WEEKS, MARY ELVIRA, "The Discovery of the Elements," Mack Printing Co., Easton, Pa., 3d ed., 1936. Many portraits and brief biographies are given.

Science Service, Washington, has portraits of many scientists for sale. The same is true of the English firm Suckling & Co., 13 Garrick St., Covent Garden, London, W.C.2.

BROWNE (ed.), "A Half Century of Chemistry in America . . . ," in the Golden Jubilee number of the American Chemical Society issued Aug. 20, 1926, as No. 8A of the *J.Am.Chem.Soc.* This issue contains the portrait of every president down to the date of publication.

Industrial and Engineering Chemistry, News Edition, has published many portraits chiefly of men active in this country.

Miscellaneous

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, "Directory of Members." The 1934 issue includes all members from June, 1929, to June, 1934—about 23,000 names. In connection with each are given the person's degrees, position, address, etc.

AMERICAN CHEMICAL SOCIETY, "Directory." It has been revised to June 1, 1935, to include a list of past presidents, various classes of members, and their geographical distribution. A list of the honorary members of this society with brief biographical notes will be found in *Ind.Eng.Chem., News Ed.*, **12**, 23–6 (1934).

GERMAN CHEMICAL SOCIETY, "Mitglieder-Verzeichnis." Issued shortly after Jan. 1 each year. The Hofmann Festschrift of this society [*Ber.* **51** (1918)] contains a list of eminent chemists whose epoch-making papers were published in this journal.

Each year the Journal of the Chemical Society, Berichte, and other journals publish a number of good biographies. Industrial leaders have been considered in Chemical Industries since March, 1935.

PERIODICALS

"By reading the old journals we come in contact with the masters of experimentation and of reasoning who have gone before . . . They laid the foundations of the science of to-day and they have much to teach us as to methods of thinking and working. . . .

If we are to add to human knowledge we must know exactly how far that knowledge has gone, at least to the point where we are to do the adding: we must find the end of a rope before we can splice a piece onto it."

E.E. REID, "Introduction to Organic Research"

Knowledge is of two kinds: experience and hearsay. The latter is divisible into that part fixed in the mind and that available as literature, *i.e.*, the recorded experience of others, or "permanent memory of man." No one knows the number of books devoted to chemistry, but a conservative estimate would place the figure at well over 50,000 volumes.[1] Obviously, with unlimited access to all libraries the fraction of published information that any one person can assimilate is very small. This is, however, no deterrent to chemically minded authors who are responsible annually for three to four hundred new books and about forty thousand articles, the latter being distributed among twenty-eight hundred journals. Huge as this volume may seem, it is essential that every research worker glean from it the advances in his special field and the trend of chemistry in general. The penalties for neglect of this obligation are severe: time wasted in rediscovering published facts[2] and obsolescence.

[1] The largest chemistry library in the world is said to be that of the Chemical Society of London. It contains about 40,000 volumes. The University of Michigan Chemistry Library has approximately 11,500 volumes.

[2] A large and well-known company hired an expert and financed his laboratory work for two years just to obtain data already in its library. These data could have been found there for a small fraction of the expenditure in time and money.

There is no excuse for repeating work already published except to develop technique or verify the conclusions of another. Neither is there any possibility of getting fresh water from a stagnant pool.

An additional duty rests upon all who would extend the boundaries of human knowledge, viz., to study the methods, reasoning, and conclusions of the masters. These are best shown in their own writings, not in the summaries of followers who may, when gathering the substance, have overlooked the spirit. Such writings are, of course, found in that most valuable part of chemical literature: original-article periodicals usually called "journals," "transactions," "memoirs," or the equivalent.

History

The art of making paper became fairly well known in Europe during the thirteenth century. Printing from movable type began about 1450, and the bookmaking industry was well started by 1500. The period 1575 to 1615 has been termed the "golden age of alchemy." Shortly thereafter persecution of scientists decreased, and the secret societies[1] began to function more openly; e.g., the "Invisible College" had held meetings for over twenty years before it became the Royal Society (of London) in 1662. Scientific literature, from 1450 down to 1650, consisted largely of books written in Latin or in mystic symbols, but with the rise of learned societies there came a demand for a permanent record of their activities and an opportunity for the scientist to make public the results of his experiments. Thus the journal literature evolved during the years 1665 to 1730.

The first periodicals were very general in nature, embracing all science, e.g., Transactions of the Royal Society, but gradually specialization developed. The first journal restricted to chemistry was published in 1778. It was Crell's Chemisches Journal. Shortly thereafter, division within the science took place through the rise of journals devoted to the two broadest branches: pure and applied chemistry. Further cleavage began

[1] The Academia Secretorum Naturae was founded in Naples in 1560; the Accademia dei Lincei, in Rome in 1603 (Galileo was a member); the renowned Accademia del Cimento, in Florence in 1657; the Académie des Sciences in Paris in 1666.

TABLE 7.—JOURNAL DATA

Journal	Year started	Frequency	Volumes per year	Current volume	Pages per volume*	Cost per year*	Indexes
Am.J.Sci	1818	m	2	[5] 33	475	$ 6.00	Cum. each 10 vol.
Analyst	1876	m	1	62	850	7.40	Ann. A & S, cum. 10 yr.
Angew.Chem	1888	w	1	50	900	19.00	Ann. A & S, cum. 20 yr.
Ann	1832	i	8–10	529	300	40.00	Each vol., 4 vol., 50 vol.
Ann.chim.(phys.)	1789	m*	2	[11] 7	500	8.25	Cum. for 20 vol.
Ber	1868	m	1	70	2,400	29.25	Ann. A, 10 yr. cum.
Bull.soc.chim.(Mem.)	1858	m*	1	[5] 4	2,100	(13.20)	Ann. A & S, 10 yr. cum.
Chem.Met.Eng	1902	m	1	44	700	3.00	Ann. A & S
Chem.Weekblad	1903	w	1	34	800	10.20	Ann. A & S
Chem.Ztg	1877	sw	1	61	1,000	19.00	Ann. A & S
Compt.rend	1835	w	2	205	2,500	21.00	Vol. A & S, cum. 30 vol.
Gazz.chim.ital	1871	m	1	67	1,000	16.00	Ann. A & S
Helv.Chim.Acta	1918	i	1	20	1,500	7.80	Vol. A & S
Ind.Eng.Chem	1909	m	1	29	1,500	7.50	Ann. A & S
J.Am.Chem.Soc	1879	m	1	59	2,800	8.50	Ann. A & S
J.Biol.Chem	1905	m	4	118	800	20.00	Ann. A & S, cum. 25 vol.
J.Chem.Soc	1848	m	1	1937	2,100	15.00	Ann. A. S, & F, 10 yr. A & S
J.Phys.Chem	1896	m	1	41	1,200	10.00	Vol. A & S
J.prakt.Chem	1834	i	3–4	149	350	20.00	2 vol. A, S, & F, 50 vol. cum.
J.Soc.Chem.Ind	1882	w	1	56	1,600†	21.00‡	

TABLE 7.—JOURNAL DATA.—(*Continued*)

Journal	Year started	Frequency	Volumes per year	Current volume	Pages per volume*	Cost per year*	Indexes
Kolloid Z.	1906	m	4	79	375	32.00	2 vol. A & S
Monatsh.	1880	i	2	70	450	23.00*	Cum. 10 yr. A & S
Nature	1869	w	2	140	1,000	14.00	Vol. name & title
Phil.Mag.	1797	m	2	[7] 24	1,200	Varies	Vol. comb. N & S, 30 yr. cum.
Proc.Roy.Soc.A	1840	m	4	159	700	7.50	Vol. A & title
Rec.trav.chim.	1882	m	1	56	1,200	11.25	Ann. A, S, & F, cum. 50 vol.
Science	1883	w	2	86	650	6.00	Vol. comb. A & S
Trans.Electroch.Soc.	1902	sa	2	72	500	13.00	Vol. cum. 20 vol.
Trans.Faraday Soc.	1905	m	1	33	1,500	15.00	Vol. A
Z.anal.Chem.	1862	i	3-4	109	465	38.50	Vol. A & S, 10 yr. cum.
Z.anorg.allgem.Chem.	1892	i	6-10	233	425	84.25	3 vol. A & S, 50 vol. cum.
Z.physik.Chem.A	1887	i	6-8	179	475	86.00	Vol. A
Z.physik.Chem.B	1928		5*	37	465	50.00*	Vol. A

Key: For each journal entry there are given the official abbreviation, frequency, volumes per year, current volume number (July, 1937), pages per volume, cost per year in dollars at the current rate of exchange. (When the number of volumes varies the price is for the maximum number usually issued.) Under the heading "Indexes" A means Author; S, Subject; and F, Formula.

* The figure is approximate only.

† Includes Chemistry and Industry and Transactions.

‡ Includes Chemistry and Industry, Transactions and Abstracts.

about 1860 with the advent of journals in special phases of pure chemistry (analytical, organic, physical) and particular industries (petroleum, rubber, paper). At present, further subdivision is in progress; for example, the journals devoted to physical chemistry are being supplemented by periodicals dealing especially with colloids (Kolloid Zeitschrift), atomic structure (Journal of Chemical Physics), etc.

Classification

Societies fostered the early journals. In some countries the universities took an active part in the establishment of periodicals. Many were started by individuals who desired more space for their fields of major interest than could be allotted by the existing journals. Today the most important magazines are still controlled by the professional groups, particularly those national in character. A few are purely business ventures, some belong to government bureaus or other institutions, but these are only a small fraction of the total number. Other classifications of journals are based upon national lines or the field covered. Since excellent lists have been published elsewhere (see p. 48) they will not be repeated here.

Trade organs

In recent years there has developed a group of periodicals, called "house organs," some outstanding members of which deserve recognition. The number of these privately published journals is very large, well over a thousand in the United States alone. All of them are obviously designed to advertise some company or product, but many are worthy of a place in any chemistry library. The Vancoram Review, Footeprints, Nickel Bulletin, Chemist-Analyst, and Metallgesellschaft, to mention only a few, should be known to everyone interested in the fields covered. The Industrial Bulletin of Arthur D. Little, Inc., and Chemical Digest of Foster D. Snell, Inc., are good examples of the publications sponsored by consulting firms.

Recent trends

During the past few years journals have faced two difficulties: a drastic reduction in funds and a marked increase in the number

of papers submitted for publication. To meet the situation a few have restricted the length of all papers so much that the published portion is essentially an abstract of the original paper. At the other extreme, certain journals have largely increased their size and raised the subscription price accordingly. The rest have taken positions somewhere between. They have accepted a smaller fraction of the articles received, insisted on brevity without sacrifice of clarity, and slightly increased the price.

Various other expedients have been suggested such as the use of smaller type or photographic reduction to increase the amount of printed matter on a unit area of paper. This would require the use of a reading machine if carried far enough to effect any appreciable economy in cost of paper. Perhaps the most important innovation is that started in January, 1937, by certain of the journals. If an article, acceptable for publication, is too long for the space available, an abstract is prepared and published in the journal concerned. The complete paper is then delivered to Science Service, Washington, from which a copy can be obtained in the form of filmstats (negatives 1 inch high on standard 35-mm. motion-picture film) or ordinary photographic prints 6 × 8 inches in size.

Journal reading

How to keep abreast of the current literature is largely an individual problem. Some chemists have solved it by devoting a short period daily to scanning the latest issues. Others spend more time once a week, while a third group depends upon the abstract journals. The scheme adopted by most workers is probably a combination of the last method with one of the others. In any case, whatever the system, it must be adequate to keep the reader up to date regarding publications in his field.

References

Any statement of fact encountered in the literature is based upon the experience of the writer. Otherwise he is relying on someone else to support his assertion. If the latter, his authority should be cited unless so well known that that is unnecessary. All references should invariably answer three questions:

Who did the work? When was it published? Where can it be found?

Current practice, as exemplified in the Journal of the American Chemical Society, requires for *article references:* the author, name of the periodical, volume number, page, and year, all in the order given. The name of the periodical may be abbreviated as shown in the Chemical Abstracts "List of Periodicals." Private systems should not be used in papers to be read by others. The abbreviation is printed in italics. The volume number of the journal is printed in boldface type. Some societies are abandoning volume numbers and substituting the year of publication. In such cases this figure should be boldface. The page is given in ordinary type. If the reference is to a whole article the inclusive pagination should be given; otherwise only the specific page upon which the statement cited appears. The year of publication follows the page number and is enclosed in parentheses. Examples:

Newman, *J.Am.Chem.Soc.*, **57**, 732 (1935).
Newman, *J.Am.Chem.Soc.*, **57**, 732–5 (1935).
Stedman and Barger, *J.Chem.Soc.*, **1925**, 247.

While the preceding forms for references are considered adequate in the majority of cases, additions such as the title of the article are occasionally made. Eliminations, except for the one noted, should be discouraged.

A *book reference* should include the author, title in quotation marks, publisher, his location, the year of publication, volume (if one of a set), and the page. Ordinary, i.e., roman, type is used throughout by the Journal of the American Chemical Society, but some other authorities use capitals and small capitals without quotation marks for the title:

Kassel, "The Kinetics of Homogeneous Gas Reactions," Chemical Catalog Co., New York, 1932, p. 150.

Mellor, COMPREHENSIVE TREATISE ON INORGANIC AND THEORETICAL CHEMISTRY, Longmans, Green & Co., New York, 1931, Vol. XI, p. 64.

This discussion should not give the impression that all authors (in the cataloging sense) have adopted the system described,

for such is far from the truth. Unfortunately the American Chemical Society does not require uniformity in its own publications. Certain steps have been taken, however, to bring about greater agreement among all publications. For example, the Chemical Abstracts' "List of Periodicals" mentioned previously has been adopted as the international standard for abbreviations by the International Union of Chemistry. This gives the list a definite status and increases the probability of its wider adoption in the near future.

Locating an article

Given a complete and correct journal reference, the task of locating the article should not be difficult. The steps are as follows:

a. Find the official title of the journal. This may usually be accomplished, for periodicals now appearing, by referring to the Chemical Abstracts' list which is arranged alphabetically according to the standard abbreviation. Many of the larger books, especially those used for reference work, give a list of journals cited and the abbreviations used. Bolton's "Select Bibliography," Vol. I, pp. 1159–64, contains 436 title abbreviations especially useful for publications antedating 1890.

b. Having the official title, consult the card catalog (see p. 21). If the library has the journal, note its call number.

c. Examine the "holdings card" in the shelf list to see if the particular volume desired is owned by the library.

d. Find the book on the shelves.

Naturally as one becomes more familiar with a particular library and its aids some of the foregoing steps may be eliminated. For example, in a certain library the librarian has noted, on the Chemical Abstracts' list, the call number of each journal available in that collection. Hence one can go directly from that list to the book on the shelf. Other libraries undoubtedly have similar short cuts.

Wrong references

The preceding directions assume that the reference is correct and the journal available. Unfortunately any extensive bibliographical work will soon prove that such ideal conditions are

not always encountered. Frequently considerable ingenuity must be exercised before the desired article is obtained.

First, as to wrong references, in general it will be found that problems of this sort are quickly solved. If a reference is incorrect with respect to only one of the five items: author, journal, volume, page, or year, the correlation of journal name with volume, and year can be checked by means of a synchronistic table (Table 8). Such tables may vary in arrangement, but all contain essentially the same data; viz., for every journal listed will be found the number of the volume corresponding to each calendar year of publication. Several of these tables are mentioned on p. 50.

TABLE 8.—PORTION OF A SYNCHRONISTIC TABLE

Year	Ber.	C.A.	Chem Zentr.	J.Am. Chem. Soc.	J.Chem. Soc.	J.Phys. Chem.	Z.anorg. allgem. Chem.	Year
1910	43	4	81	32	97–8	14	65–8	1910
1911	44	5	82	33	99–100	15	69–72	1911
1912	45	6	83	34	101–2	16	73–8	1912
1913	46	7	84	35	103–4	17	79–83	1913
1914	47	8	85	36	105–6	18	84–9	1914
1915	48	9	86	37	107–8	19	90–3	1915
1916	49	10	87	38	109–10	20	94–8	1916
1917	50	11	88	39	111–12	21	99–101	1917
1918	51	12	89	40	113–14	22	102–4	1918
1919	52	13	90	41	115–16	23	105–8	1919
1920	53	14	91	42	117–18	24	109–14	1920
1921	54	15	92	43	119–20	25	115–19	1921
1922	55	16	93	44	121–2	26	120–5	1922
1923	56	17	94	45	123–4	27	126–31	1923
1924	57	18	95	46	125–6	28	132–41	1924

NOTE.—The entire table will be found on pp. 1496–9 of Lange's "Handbook of Chemistry," Handbook Publishers, Sandusky, Ohio, 2d ed., 1937.

With the right volume, if the page number is wrong, the annual index, covering that volume, should give the right page under the author's name or the subject. Incidentally, one of the commonest errors is inversion of either volume or page numbers, e.g., Vol. 54 for Vol. 45, or p. 234 for p. 243.

The next sort of error, author incorrect, is of minor importance. It will usually give no trouble. If a reference is entirely wrong the right one may often be found by consulting the subject indexes of abstract journals or other literature on the same topic, some idea of the age of an article always being most helpful.

Journal not available

When the journal containing a desired paper is not available locally the article may possibly be found reprinted in another journal either verbatim or in a slightly altered form or translated into another language. For example the Chemical News frequently reprinted articles initially appearing in other English and American journals. Several German journals print translations of articles, especially from the Russian periodicals. If the search for a reprint is fruitless it may be worth while to compare the abstracts in the various abstract journals. Often a summary will be found entirely adequate for the work involved. In any event one should hesitate to say that an article is not in a particular library until he has exhausted the possibilities mentioned.

The conclusion having been reached that it will be necessary to look elsewhere for a paper, the next aid is Gregory's "Union List of Serials." This is an alphabetical arrangement of the titles of practically all periodicals to be found in any library in the United States or Canada. Under each title are given (*a*) the various libraries having that journal and (*b*) the specific

TABLE 9.—AN ENTRY FROM GREGORY'S "UNION LIST OF SERIALS"

SOUTH African chemical institute
To Jl 1921 as South African association of analytical chemists
Journal 1, 1918+
Index: 1–5

CU	1+	ICJ	1+
DA	1+	IU	4+
DLC	1+	PPF	3+

Proceedings . . . Cape Town. 1912/13+

CU	1914+	ICJ	1+
DA	1920+	IU	1920+
DLC	1912–22, 24/25+		

Key.—The Institute has published a journal since 1918. A complete set is on file at CU (University of Calif.), DA (U.S. Dept. Ag. at Washington), DLC (Library of Congress), and ICJ (John Crerar Library, Chicago). IU (Univ. of Illinois) has a complete set excepting Vols. 1, 2, 3; PPF (Franklin Institute of Philadelphia) lacks Vols. 1 and 2, etc. The key to all abbreviations is given under the covers of the Union list and in the Introduction.

volumes possessed (see sample entry, Table 9). A brief examination of the Chemical Abstracts' register will reveal that it also is a union list since it mentions the libraries having each journal entered. The important difference is that no information is given regarding the particular volumes to be found in any one collection.

When the location of a desired article is known it may be examined by (*a*) visiting the library, (*b*) obtaining the volume for a few days through the Interlibrary Loan service available at practically all of the larger libraries, (*c*) ordering a photographic copy. The Chemical Abstracts list mentions the libraries having photostat and filmstat service. In either case the cost is nominal, and the copy may be filed for future reference.

Journal appraisal

Technical papers are seldom read for entertainment. They are studied for information that may help to solve other problems. Only to the extent that a reader can interpret and apply published results to his own work will they be of any assistance to him. Hence a trio of obligations exists resting upon the author, the journal, and the reader. The author must write lucidly of his experience and ideas; the journal must provide a reasonable amount of space for the exposition; and the reader needs sufficient technical training and experience to appreciate and interpret the discussion. Partial failure of any one of the three agents materially hinders the transfer of knowledge. The value of a scientific periodical, therefore, is determined chiefly by the quality of its articles. These can be considered adequate only when each communication will enable another chemist to repeat the calculations or experiments, form a good estimate of the accuracy of the results or soundness of the conclusions, and apply the technique to a similar problem.

Naturally any critical evaluation of a journal will depend, to a large extent, on the reader's ideal. If he has some notion of what demands a periodical should meet, a decision can be reached very quickly. If criteria are lacking, the first step may well be a study of the authors, i.e., the number and frequency of articles by reputable men. Another factor is the promptness of publication. There are usually legitimate reasons for delay in particular

cases, but when the "date published" is consistently nine months to a year later than the "date received" the journal cannot honestly claim a place in the vanguard of scientific-news distributors. Other features deserving some consideration are the sponsors, the field covered, and special sections. In connection with the latter, book reviews and biographical notes are often deemed valuable.

Incidentally, an important by-product of the critical examination suggested in the preceding paragraph is the acquisition of a sense of direction when making a survey. This is especially true when browsing must be employed as a last resort. Skilled searchers quickly find desired information chiefly because they know where to look. For example, one would not ordinarily look in the Zeitschrift für analytische Chemie for the preparation of an organic compound, but such directions are to be found there occasionally especially when the product is used as an analytical reagent.

Reading an article

With the preceding discussion as a background very little additional needs to be said about the technique of reading an article. The first step is an appraisal of the work, a rapid survey to determine whether it contains anything applicable to the reader's field. If so, a careful study should be made to ascertain the author's objective. His procedure should be scrutinized to make sure that all interferences and variables were given due consideration and that facilities were satisfactory. The results should be checked and their adequacy in supporting his conclusions questioned to prove that some other interpretation will not more accurately fit the data. Finally, before experimental verification is resorted to, the status of the writer should be noted. What is his reputation? Is the article under consideration his first on the subject? What is his background or training for the work? What is the date of the article with reference to the state of the art? In other words, would modern equipment be likely to yield different results? Having covered all of these points one can feel fairly confident that the article has been well read. As such a procedure is continued a background will gradually be acquired making it possible to judge rapidly the worth of any article, a most desirable asset for the research worker.

Corrections

Occasionally errors creep into journal articles. They may be typographical or experimental. If the former, many editors will insert a note in a subsequent issue calling attention to the error and indicating the necessary correction. Such a note may appear as filler at the bottom of a page, in a separate section as a "Communication to the Editor," on inserted slips of paper, or on a special sheet at the end of the book. Since no uniformity in procedure exists, the policy of each individual journal must be ascertained by inspection.

Experimental errors are also handled in a variety of ways. The author (or someone else) may write a "Note" to the editor calling attention to the fault and revising any conclusions based thereon. An article may be published explaining the source of the mistake and giving the correct data. If this article has the same title as the original paper or is otherwise definitely related to it the correction may be located readily. On the other hand if the author mentions the error incidentally in a subsequent paper, perhaps on a distantly related subject, he obviously sets a trap for an unwary follower. Nevertheless, the correction having been made, he is protected from attack. As a result it behooves anyone studying the literature to make a diligent search for amendments to any statement believed inaccurate. The mode of procedure will be indicated by the policy of the journal involved and the possible variations just enumerated. Of course it should be understood that German journals often call attention to errors in the "Inhalt" under the headings "Druckfehler" or "Berichtigungen." Corresponding terms might be used in other languages. Even if a reasonably thorough search reveals nothing, before spending very much time and money on the problem it is usually best to communicate with the author directly and ascertain his attitude.

Language difficulties

A few years ago Gross and Gross made a study of the references in Vol. **48** (1926) of the Journal of the American Chemical Society. They found that, of those not involving American periodicals, 52.5 percent referred to German articles, 35.2 percent to English, 9.4 percent to French, and 2.8 percent to all others. Seven years later Sh

found that his figures were only slightly lower. Readers of this book will also note the relatively large number of German books mentioned. This situation is probably due to the fact that the Germans have always contended that any information published should be available in their language. Hence they have spent much time and money compiling some of the finest reference books in the world. These will not be translated into English. Consequently research men in chemistry must be able to read German. While a knowledge of French, Russian, and Italian may be desirable, German is essential. Some aids are mentioned in the bibliography for those who have mastered the fundamentals.

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ABSTRACT JOURNALS

> *"Success in reading depends upon the possession of certain somewhat technical skills. Chief among these are skill in finding the specific pages which will yield desired information and skill in gleaning knowledge from the printed page."* HEADLEY, "Making the Most of Books"

History

The birth of scientific periodicals took place shortly after 1660. The first exclusively chemical journal was started over a century later (1778) and appeared, under various titles, for 25 years. This publication was edited by Crell. It had at least three objectives: to announce new books, print new articles, and give summaries of papers initially appearing elsewhere. During this time other periodicals, more or less chemical in nature, also published reviews. The first journal devoted exclusively to chemical abstracts was the *Pharmaceutisches Centralblatt*, started in 1830 and continued, with some modifications in name and scope, down to the present time. In 1858 the French Chemical Society started to publish abstracts in its "Bulletin." Thirteen years later the *Journal of the Chemical Society* (London) began to appear with an abstract section. In the field of applied chemistry the *Journal of the Society of Chemical Industry* started to print abstracts in 1882. The *Zeitschrift für angewandte Chemie*[1] waited until 1887 to introduce this form of service.

European activities were thus well under way when a group of faculty members at the Massachusetts Institute of Technology launched the *Review of American Research*. This was published in the *Technology Quarterly* from 1895 to 1901 and as a part of the *Journal of the American Chemical Society* from 1897 to 1906. The following year *Chemical Abstracts* was started. In 1919 the *Zeitschrift für angewandte Chemie* ceased publishing abstracts, and the *Chemisches Zentralblatt* took over the work. At the same time it adopted the subtitle "Vollständige Repertorium

[1] At that time it was called the *Zentralblatt für technische Chemie*. It now bears the title *Angewandte Chemie*.

für alle Zweige der reinen und angewandten Chemie." Later (1925) a movement to combine the British abstracting activities was initiated in England. *British Chemical Abstracts* was established, and the abstract section of the *Journal of the Chemical Society* became Part A of the new journal; the abstract section in the *Journal of the Society of Chemical Industry* became Part B. The final step, combination of the two divisions under one cover, has not yet been effected.

Thus by the close of the eighteenth century a German movement of inestimable value to the chemical world had been initiated. During the following century it spread to other countries and today is fostered by the national society as well as by a large number of lesser organizations whose ambitions are more modest.

Despite the early founding of abstract journals, before 1907 there was practically no attempt, by any one publication, to include all branches of chemistry from all countries. Even after that date the effort was only partly successful because the important field of patent literature was incompletely covered. Today there are only two journals, Chemical Abstracts and the Zentralblatt, that claim to make a thorough survey of all chemical publications.

Purpose

The statement was made in an earlier chapter that about 40,000 articles of chemical interest are published annually. Obviously it is futile to suggest that any one person sift this volume of material for the few contributions pertinent to his own work. First, the entire output cannot be found in any one place; second, the number of languages is too great for any individual to master; and, third, it would be necessary to examine a hundred articles every day in the year. Of course the journals might be purchased, and a corps of assistants hired to scan them—a rather expensive method. If only a limited number of periodicals were involved one of the abstracting agencies, e.g., Engineering Index Service or H.W. Wilson Company, both in New York City, might be induced to undertake the work. Each prepares abstracts on index cards, ready for filing. The fee is calculated from the number of journals involved. Another alternative

is to subscribe to an abstract journal. This immediately raises a question concerning the relative merits of the publications available, a point to be considered later.

The primary demands generally placed upon an abstract journal are two: information about the latest developments in chemistry, and assistance in searching the literature for specific facts. The first need really implies completeness more than up-to-date news. One naturally turns to the current articles themselves for the latest accounts and depends upon abstracts to indicate material missed as a result of publication in less readily available serials or unfamiliar languages. In other words, the first criterion of the value of abstract journals is the thoroughness with which they embrace the whole field of chemistry. Original and review articles, patents, books, doctoral dissertations, and any other literature dealing with the subject should be mentioned in a journal truly surveying the entire field. While Chemical Abstracts and the Zentralblatt are the only publications striving for this goal, neither has actually reached it.

The second need, assistance in searching the literature, involves the preparation of adequate indexes, undoubtedly the most important function of any abstract journal. Some scientific groups prepare no abstracts but devote all of their time and energy to the indexes. Naturally, opinions vary regarding this attitude, but there can be no question about the value of a good directory. Probably the most useful of these is the subject index, followed closely by the author guide. A more recent invention is the formula index originally used by Richter when constructing his key to the literature of organic chemistry, and later by Hoffmann for inorganic chemistry, then adopted by Chemical Abstracts in 1920 for both fields. The Zentralblatt took up this work a few years later. The only other major guide compiled by abstract journals is that of patent numbers. These four indexes plus adequate coverage are today the most essential features of an abstract journal.

Promptness

A brief study of promptness has been made as follows. Six articles were selected from each of three outstanding publications.

Then the time, in months, elapsing between the date each article was published and the appearance of the abstract in each of three important abstract journals was calculated. The results indicate that abstracts appear soonest for articles published in the same country as that of the abstract journal, the average time lag being slightly less than three months. Summaries of contributions published in foreign journals require approximately one month longer than those appearing in domestic annals.

Arrangement

Abstract journals offer several aids to anyone searching the literature. In a single number the abstracts are grouped on the basis of subject. Cross references are given (Table 11), and an author index is provided. Annual and cumulative indexes are also available. Such helps are worthy of closer examination.

The arrangement of abstracts on the basis of subject in individual issues of a journal involves several features. First there is a lack of agreement among the journals regarding divisions. This is shown in Table 10. Of course it is true that, for the three journals listed, many of the sections bear the same title. On the other hand the Zentralblatt has no "Apparatus" section, British Chemical Abstracts has a place for "Reactions," etc. The placing of individual abstracts is, however, more important. Those that unquestionably belong to a particular division will probably be found there, but the locating of material on analytical chemistry, for example, is not so easy. The Zentralblatt has a single section for such reports; the others do not. Chemical Abstracts reserves its "Analytical" division for articles of general interest in pure chemistry, abstracts on the analysis of foods, glass, fuel, etc., being assigned to sections dealing with the particular material involved. When an abstract thus placed is considered of sufficient general interest a cross reference will be found in the analytical section. This is helpful, but the chemist, active in any particular field, should not complacently confine his reading to a single section of his favorite abstract journal until convinced that there is nothing of interest to him in the other sections.

The device of section-to-section references is used in Chemical Abstracts, as stated in the preceding paragraph. It is also

TABLE 10.—ABSTRACT JOURNAL SECTIONS

Chemical Abstracts	British Chemical Abstracts	Chemisches Zentralblatt
1. Apparatus	*A. Pure Chemistry*	*A.* General and Physical (4 divisions)
2. General and Physical Chemistry	I. General, Physical, and Inorganic Chemistry	*B.* Inorganic
3. Subatomic Phenomena	Sub-atomics	*C.* Mineralogy and Geology
4. Electrochemistry	Molecular Structure	*D.* Organic Chemistry
5. Photography	Crystal Structure	General and Theoretical
6. Inorganic Chemistry	Physical Properties of Pure Substances	Synthetic
7. Analytical Chemistry	Solutions and Mixtures	*E.* Biochemistry (6 divisions)
8. Mineralogical and Geological Chemistry	Kinetic Theory Thermodynamics	*F.* Pharmacy
9. Metallurgy	Electrochemistry	*G.* Analysis
10. Organic Chemistry	Reactions	*a.* Elements and Inorganic Compounds
11. Biological Chemistry	Methods of Preparation	*b.* Organic
12. Foods	Analysis	*c.* Plant and Animal Materials
13. Chemical Industry	Apparatus	*d.* Medicine . . .
14. Water, Sewage . . .	Geochemistry	*H.* Applied Chemistry
15. Soils . . .	II. Organic Chemistry	I. General Chemistry Technology
16. Fermentation Industry	Aliphatic	II. Industrial Hygiene
17. Pharmaceutical Chemistry	Homocyclic	III. Electro-technics
18. Acids, Alkalis . . .	Terpenes	IV. Water, Sewage
19. Glass, Clay, . . .	Heterocyclics	V. Inorganic Industry
20. Building Materials	Alkaloids	Silicates, Building Materials
21. Fuels	Organo-metallic Compounds	Agricultural Chemistry
22. Petroleum	Proteins	Metallurgy
23. Cellulose and Paper	Analysis	Organic Industry
24. Explosives	III. Biochemistry (15 divisions)	X. Dyeing
25. Dyes, Textiles	*B. Applied Chemistry*	Resins
26. Paints, Varnish	I. General, Plant . . .	Rubber
27. Fats, Soaps	II. Fuel, Gas . . .	
28. Sugar, Starch	III. Organic Intermediates	
29. Leather, Glue		
30. Rubber, . . .		

TABLE 10.—ABSTRACT JOURNAL SECTIONS.—(*Continued*)

Chemical Abstracts	British Chemical Abstracts	Chemisches Zentralblatt
	IV. Dyestuffs	Perfumes
	V. Fibers, Textiles . . .	Sugar
	Bleaching, Dyeing . . .	XV. Fermentation
	Acids, Alkalis . . .	Foods . . .
	Glass, Ceramics	Fats, Waxes . . .
	Building Materials	Fibers . . . Rayon
	X. Metals, Metallurgy	Fuel
	Electrotechnics	XX. Explosives
	Fats, Oils, Waxes	Leather
	Plastics, Paints	Glue, Gelatin
	India Rubber	Inks, Polishes . . .
	XV. Leather, Glue	Photography
	Agriculture	Bibliography
	Sugars . . .	
	Fermentation Industry	
	Foods	
	XX. Medicinals	
	Photographic Materials	
	Explosives	
	Sanitation	

employed in British Chemical Abstracts, Part B but not Part A. The Zentralblatt apparently does not use the scheme to any extent.

Finally, there appears to be no system for arrangement of article abstracts within a division except that those on the same or related topics may be placed together. Subdivisions based on the sorts of material covered are arranged as shown in Table 11.

Author indexes in current issues of an abstract journal are particularly valuable to the mature chemist. It takes him only a few minutes to examine each index for the name of any scientist likely to publish papers of interest in a particular field and thus assures him of familiarity with the recent publications.

These indexes are of minor value to a beginner unless he wishes to look up an article published during the current year. Then, if he knows the author's name, the index is of real service, even considering the fact that seven or eight individual issues[1] must be consulted.

TABLE 11.—ARRANGEMENT OF ENTRIES WITHIN A SECTION

Chemical Abstracts	British Chemical Abstracts	Chemisches Zentralblatt
Articles	*Part A*	Articles
Cross references	Articles only	Patents
Books	*Part B*	Books
Patents	Articles	
Theses	Cross references	
	Patents	
	Cross references	

Thus far the discussion has been confined to the use of abstract journals for the purpose of keeping up to date. As keys to the literature for "state-of-the-art" searches, the journals require examination from a slightly different angle.

Value

The value of an abstract journal, as a guide to sources of information, depends upon three factors: quality of the abstracts, adequacy of the indexes, and completeness with which the entire field has been covered. An abstract is essentially an annotated reference. Its function is to direct the reader to an original publication, state its nature whenever the title is inadequate, and summarize the new material to be found there. The purpose of the summary is not to obviate the examination of original articles but to show which ones may contain data pertinent to the problem being investigated. In this connection the searcher must realize that an abstract embraces the activities of at least four people all of whom need to have the same concept of the idea involved if the path is to be clear from the article through the abstract to the indexes and back.

[1] It is strange that the abstract journals do not employ the cumulative system in which each succeeding index includes the entries of all previous issues for at least 3 months of the year.

First there is the author. If he has presented his thesis in unambiguous terms, has omitted no important points, and has been guided in his writing by the fact that no one else possesses his experience as a background, then and then only will the writing have been well done. In so far as he has failed there may be misunderstanding of his work.

Next comes the abstractor. He must fully comprehend the article, be skillful enough to express the essential features in a few words, include everything that is new, omit nothing important,[1] accurately present the author's ideas, and write his summary in good style.

Third, there is the indexer. He prepares, from the abstract alone, all of the subject entries, selecting words that the average chemist would be likely to look for when wanting information given in the original article. Thus the abstractor is indirectly responsible for the integrity of the index, while the compiler is directly liable for its uniformity, nomenclature, and simplicity.

Finally, the fourth member of the group, the chemist who uses the index, must assume his share of the responsibility for finding what he needs. He must possess a knowledge of the scope, arrangement, and peculiarities of the index to be used. He must realize that an idea can be expressed in more than one way; that experiments have settings, one feature often being emphasized to the neglect of another. When revealing the content of chemical literature the abstractor and indexer go only a certain distance. The searcher must travel the rest of the way himself. For the purely obvious the former may be blamed if the quest is unduly prolonged, but for a search beyond the obvious, where ingenuity is required, the time consumed and ultimate success will depend upon the experience, perspective, and intuition of the searcher.

[1] This is always a difficult problem. The abstractor must assume that he is writing to those "skilled in the art," hence is justified in ignoring what, in his judgment, is not essential to the main idea in the article. For example, a certain paper on aluminum chloride contains a description of the electric furnace used when preparing that compound. The abstract clearly outlines the process but does not mention the furnace. Perhaps the abstractor erred; but whatever one's opinion, the case indicates what is known to every experienced searcher, viz., that it is necessary to go beyond an abstract in order to find the wealth of "hidden" information in the journals.

Use of indexes

Four indexes: author, subject, formula, and patent, are prepared by the more valuable abstract journals. When using any one of the four, an important point to ascertain is its scope with respect to the information needed. The Zentralblatt, for example, did not cover technical articles before 1919, yet much time has been wasted searching the earlier issues of that journal for references to commercial data. Also, if the data desired are more in the realm of physics than chemistry, Science Abstracts, Section A, might be a better source than chemical journals.

Efficient use of an index requires a knowledge not only of its scope but also of its organization and individuality. Both of these features can be discussed more adequately with reference to particular types of indexes, hence will be considered in the following sections.

Use of author indexes

An author index is a list, chiefly, of personal names arranged alphabetically according to surname. Fortunately pseudonyms are seldom used in scientific work, and so it would appear that there is nothing difficult about finding a name. This is true if the searcher knows what the name is and how to spell it. Suppose, however, that a man, Fischer, has published a desired article. If nothing more is known about him the problem is far from simple. A glance at the Third Decennial Index to Chemical Abstracts will reveal 304 entries distributed among ten H. Fischers, all believed by the indexer to be different people.[1]

H. Fischer	Hellmuth Fischer
Hans Fischer	Herbert Fischer
Harry Fischer	Herm. Fischer
Heinrich Fischer	Hermann Fischer
Hellmut Fischer	Hugo Fischer

Just to suggest a few complications, assume that the Fischer sought is one of the ten and that he has been slightly erratic in signing his name, using H. Fischer, Herm. Fischer, or Hermann Fischer at various times. Suppose also that the printer omitted

[1] This example is taken from "Why Indexers Turn Gray," by E.J. Crane, *Ind.Eng.Chem.*, *News Ed.*, **15**, 175 (1937).

the *c* now and then. Without further supposition the number of possible name entries for this one man has increased to six excluding the likelihood of someone else being entitled to use any of the variations. Of course the indexer does his best to avoid entanglements of this sort, but he is not omniscient.

Next there is the prefix problem. Fortunately it is readily solved once attention has been called to its existence. Rules are given in the second chapter for the arrangement of names beginning with *von*, *van*, *de*, *la*, etc., but they apply only to the library catalog, and even there they are subject to the qualification that a name should be entered as used by the owner. Georg von Hevesy, for example, is entered under H, while Wolfgang von Oettingen will be found under V in catalogs using Library of Congress cards. When author indexes of abstract journals are examined they fall into three classes: those ignoring prefixes, those consistently using them, and those apparently following no rule. The obvious solution is to look in both places when the system used is not known or when no cross reference is given.

Certain other author index difficulties occasionally arise which may be annoying. Take, for example, the name of the famous Russian chemist who discovered the reagent used to detect and determine nickel. In German indexes his name is entered as Tschugaeff, but in Chemical Abstracts it is found as Chugaev. This difference arises, of course, through the lack of uniformity in converting—transliterating—Russian sound symbols into Latin letters.[1] Also, there is no rule to follow when looking up the name of a married woman if only her maiden name is known. Madame Marie Sklodowska Curie did not use her maiden name in scientific papers. Her daughter, Madame Irène Joliot-Curie, in order to preserve her identity, merely added her husband's name to her own. Fräulein Ida Tacke, on the other hand, ceased to use her maiden name when she became Frau Noddack a few years ago. Incidentally a corporation may change its name for one reason or another. If the searcher is aware of the new name, well and good; if not he may be unable to carry his investigation beyond the date of

[1] Cf. CRANE, *Ind.Eng.Chem.*, *News Ed.*, **15**, 230–1 (1937).

the change. Lastly, a Spanish author has three choices. He may, and frequently does, use his mother's maiden name or his father's name or the two combined.

In conclusion, it should be borne in mind that, with over fifty thousand people writing articles of chemical interest each year the author indexes are surprisingly easy to use, especially when one is aware of their peculiarities.

Use of subject indexes

An index is a tool used to find information. Its nature is determined by the intent of the designer, but its effectiveness depends upon the knowledge and skill of the user. A subject index is a special instrument theoretically consisting of an alphabetical arrangement of subjects but actually varying from a classified list of titles, many of which offer no hint as to the actual subject matter, to a detailed content inventory of the literature covered.[1] An example of the former type is Science Abstracts, Section A; of the latter, Chemical Abstracts. Intermediate forms are represented by the International Catalog of Scientific Literature and the Engineering Index. Within any particular type there are variations in format and details of arrangement, as will be observed by comparing the subject index of Chemical Abstracts with that of the Zentralblatt (Table 12).

Certain details of placement are based upon arbitrary rules irrespective of the language in which the index is printed. A specific instance is the naming of organic ring compounds. Examples of this feature are numerous in every index. A second illustration is the use of Latin or Greek prefixes denoting numbers. The substance $(C_6H_5)_2$ may be entered under b̲iphenyl in one index, under d̲iphenyl in another. Information regarding such points is usually given in the introduction or preface to each index.

An appreciation of the implications of subject headings is probably the most important factor in the successful use of a subject index. When an article is published dealing with some property of an element or compound it must be assumed that

[1] FULCHER, G.S., "The Indexing of Scientific Articles," The National Research Council, Washington, Reprint and Circular Series, No. 34, 1922.

the author first obtained a sample of the pure material. Consequently, if a method for the preparation of any substance is desired it should be found in a report on the determination of the atomic weight, melting point, boiling point, or some other property of that substance. The preparation of pure silver, for example, is more likely to be found by use of the heading "Chlorine, atomic weight," than by searching for "Silver, preparation of."

This leads directly back to the statement that experiments have settings. A mode of procedure must be established; apparatus of the right type must be properly assembled; raw materials must be obtained, suitably prepared, and tested for quality; concentrations, temperatures, pressures, and humidity must be controlled if necessary. Some of these features are essential to every experiment and therefore are implied in a subject heading calling attention to the published results. It is assumed that anyone using an index will have some knowledge of his subject and be able to visualize it in various settings other than the specific one contemplated. Even though the words he would use to express his idea cannot be found in the index he will still be able to locate the information through association and placement of that idea in other surroundings. Furthermore, antonyms as well as synonyms must be considered as headings. Also inversion of words may be employed to place an entry under a more general subject. If ferrous iron is oxidized something must be reduced at the same time. Hence, when looking for information on "Iron, oxidation," other entries such as "Manganese, reduction," "Dichromate, reduction," etc., should not be ignored. Other relationships may be equally helpful. For example, knowledge of the composition of "Aluminum flake" was needed recently. The specific entry was not found in any index, but a study of the uses of aluminum compounds indicated that some of them are employed in the rubber industry. Then a reference was located under "Rubber, compounding, aluminum in," which gave the desired information.

Another illustration involves a paper entitled "A Study of 7-Iodo-8-hydroxyquinoline-5-sulfonic Acid as a Reagent for the Colorimetric Determination of Ferric Iron."[1] In the subject

[1] Yoe and Hall, *J.Am.Chem.Soc.*, **59**, 872–9 (1937).

TABLE 12.—SAMPLES OF SUBJECT INDEXES OF ABSTRACT JOURNALS

Chemical Abstracts	British Chemical Abstracts	Chemisches Zentralblatt
Copper. (See also *Fungicides; Insecticides; Sprays.*) affinity of metals for, on aluminum wire, annealing, boiling point of, books: as catalyst, chem. and metallurgical properties of cohesive forces of, deformation of, density and energy changes in cold worked, ductility in annealed, elastic consts. of, forgings, gas pipes, hardness of, oxidation, physical properties of deoxidized, tensile fatigue strength of hard, thermal resistance of, wire—see Wire working, **Copper, analysis.** **Copper, metallurgy of** **Copper alloys.** **Copper bromides.** **Copper chlorides.** CuCl manuf. of, prepn. of, $CuCl_2$ **Copper compounds.** complex, of bivalent Cu, prepn. from burned pyrites, **Copper fluoride.** **Copper halides.** **Copper salts.**	Copper forging of hardening of thermal expansion of annealed Copper alloys Copper compounds Copper salts Copper arsenate chlorides, basic halides Cupric bromide chloride sulfate sulfide Cuprous chloride iodide sulfide Copper organic compounds Copper detection, determination, and separation Copper tubing Copper wire	**Kupfer** siehe auch *Galvanotechnik;* **Geschichte u. Allgemeines.** **Vorkommen.** **Gewinnung, Verarbeitung u. Verwendung.** Weiterverarbeitung. **Mechanische Formgebung:** Walzen auf einer Mannesmann-Anlage . . . Giessen v.—Drahtbarren; Drahtziehverss . . . Kraft, Ziehen u. Wandstärke beim Ziehen v.—Rohren ohne Dorn. **Wärmebehandlung: . . .** Verwendung. **Physikal. Eigenschaften u. chem. Verhalten.** Mechanische Eigenschaften Untersuchungsmethoden, Analyse. Kupferlegierungen Kupferverbindungen Kupfer (I)—bromid Kupfer (II)—bromid Kupferchloride CuCl $CuCl_2$ Kupferhalogenide Kupfer (I)—jodid Kupferglanz Kupferzahl

index of Chemical Abstracts this article may be found under (*a*) 5-Quinolinesulfonic acid, 8-hydroxy-7-iodo; (*b*) Iron, analysis, detn. of ferric; and (*c*) Ferron. Perhaps there is also an entry under (*d*) Colorimetry and (*e*) Reagents. Regardless of the specific headings would any inexperienced chemist, seeing these entries, suspect that the article contains an excellent account of the general procedure for testing a compound to determine its suitability as a colorimetric reagent? If he were studying some other reagent and an alkaline earth metal, unless forewarned he would probably pass right by this work and so lose the benefit of Yoe's 10 years' experience in the field.

When making a literature search, therefore, the first step is to prepare a list of subject, or search, headings both normal and inverted, placing at the top the most specific and at the bottom the most general that might include the desired information. Then as the indexes and articles are examined other headings will be suggested which can be added to the list until the search is ended or the law of diminishing returns stops the work.

Suppose that the literature on coordination complexes is to be examined. With inversions ignored, probably the first headings to search would be

Coordination
Coordination complexes
Coordination compounds
Coordination number

Headings added later might include

Bonds, covalency
Chelate compounds
Chelation
Cobalt, complex compounds of,
  coordination compounds of,
Covalency
Platinum, complex compounds of,
  coordination compounds of . . .

Then, because their names are intimately connected with the development of our knowledge in the field, it would be well to examine the publications of

Hantzsch
Jørgensen
Sidgwick
Werner . . .

Unsatisfactory headings for the search, because their relationships are too distant, would include

Chemical compounds
History
Inorganic chemistry
Nitrogen compounds
Reagents

Perhaps a better understanding of the whole problem can be gained from a study of Table 12 which contains a portion of each of the three subject indexes mentioned there and covers essentially the same subject matter, viz., copper. Page numbers and apparently irrelevant entries have been omitted as well as minor typographical variations. Otherwise the headings are the same as those in the original indexes. Considering only this table, under which headings should one look for information about the ductility of copper or the solubility of cuprous iodide? It will be immediately obvious that there is only one specific entry covering the former, none for the latter, but there are several that might lead to the desired data in both cases. Unfortunately no one can accurately predict the exact entry under which a particular item will be found, but certainly the possibility of success can be estimated from the relevancy of the entry to the property involved.

Before considering the individual periodicals attention should be called to the fact that very often encyclopedia articles or reviews are more satisfactory than abstract journals as a starting point for a general survey of a field or preparation of a bibliography. These summaries, usually prepared by experts, indicate the important papers, give selected references, save considerable time, and furnish a good background for further work.

BIBLIOGRAPHY

General

Reuss, Jeremias D., "Repertorium commentatiorium a societatibus litterariis editarum secundum disciplinarum ordinem

digessit," J.D. Reuss, Göttingen, 1803. There are 16 volumes of which the third, "Scientia naturalis," is devoted to chemistry and metallurgy and covers the period 1665–1800. This forms an excellent antecedent to the "Catalog of Scientific Papers" of the Royal Society.

Royal Society (London), "Catalog of Scientific Papers," Cambridge University Press, London, 1914–25. This monumental index lists, alphabetically by authors, all scientific papers published during the nineteenth century. Subject indexes are being prepared, but the one for chemistry has not been issued.

"International Catalogue of Scientific Literature," published for the International Council by the Royal Society of London, 1902–19. Intended to supplement the "Catalogue of Scientific Papers," this work was issued in 17 parts for each year, Section D being "Chemistry, Author and Subject Index." The financial burden became so great that activities ceased after publication of the 1914 volumes.

Abstract journals

Chemical Abstracts. Published twice a month on the tenth and twentieth by the American Chemical Society at Easton, Pa. (The editorial office is at Ohio State University, Chemistry Bldg., Columbus, Ohio), 1907–

Indexes:
- In each issue—Author only
- Annual—Author, subject, formula (1920–), patent number (1912–14, 1935–)
- Cumulative—Author and subject decennially, 1917, 1927, 1937

"The most comprehensive periodical of its kind now appearing." About 2,800 journals are searched for papers of a chemical nature, and some fifteen or twenty other abstract journals are checked to locate and rectify omissions. More attention is given to the subject index than to any other feature. References in the indexes issued before 1934 indicate pages of the volumes cited. In January of that year a new format was adopted which made it advisable to number columns instead of

pages. Each reference carries a small exponent indicating, in ninths, the distance down from the top of the page or column that the abstract is to be found. The "Subject Index Key" and "Formula Index Key" should be read to facilitate the use of these indexes. A list of the abbreviations employed and their significance will be found in each annual subject index.

Chemisches Zentralblatt. Published by the Verlag Chemie for the Deutsche Chemische Gesellschaft, Berlin. Issued weekly to form an annual volume of two parts. This journal was started in 1830 as the Pharmaceutisches Central-Blatt. The name was changed in 1850 to Chemisches-Pharmaceutisches Central-Blatt, in 1856 to Chemisches Central-Blatt, and in 1907 to Chemisches Zentralblatt. There was one volume per year down to 1889. Two volumes appeared annually from 1889 to 1919, and four volumes from 1919 to 1924. During the latter period Vol. I and III were "Scientific"; II and IV were "Technical" and covered the field formerly served by the Zeitschrift für angewandte Chemie. Since 1924 there have been two volumes each year.

Indexes:

- In each issue—Author only, on colored paper
- Semi-annual—Author, patent (1897–), subject (1889–1924)
- Annual—Subject, organic formula (1925–), corrections
- Cumulative—Author, subject, errors, 1870–81
  - Author, subject, patent, errors, every 5 years from 1897 to 1921
  - Author, subject, patent, organic formula, and errors, for the periods 1922–24, 1925–29, 1930–34

"Probably the most important abstracting journal because of the period covered." Many of the individual abstracts are more detailed than those in Chemical Abstracts. The organic and patent divisions are especially good; the latter, however, was of minor importance before 1918. During the period 1922–26 *Bibliographia chemica* was published as a supplement to the Zentralblatt. It contained a classified list of new books. This

material now appears in the journal itself and is specially indexed on the front cover of each issue. When using the subject index for the first time the "Vorwort" should be consulted for peculiarities of arrangement. A few examples are: ferric chloride is entered under "Eisen III chloride"; abstracts of articles on patents (Patente, or Rechtsschütze) may be entered under "Chemische Industrie"; some English words have been borrowed by the Germans, as "cracken" for "cracking" (in connection with petroleum).[1]

British Chemical Abstracts. The Bureau of Chemical Abstracts, London 1926– . Published in two parts: Part A, "Pure Chemistry," appears at the end of each month; Part B, "Applied Chemistry," was issued fortnightly from 1926 to 1936 but now appears monthly as a supplement to Chemistry and Industry. It is usually bound separately at the end of the year. This arrangement in two parts was started in January, 1926. Previous to that date the Journal of the Chemical Society (London) published abstracts on pure chemistry, and the Journal of the Society of Chemical Industry issued abstracts on applied chemistry (see below). There was, however, a great deal of duplication; hence the system outlined was inaugurated with the intention of ultimately combining Parts A and B under one cover. The final step may be taken in the near future.

Indexes:
- In each issue—Author only
- Annual—Author, subject, patent, errata. A list of the journals abstracted is also given
- Cumulative—Author and subject for 1923–32, 1933–7

In general, organic abstracts predominate in Part A, although it claims to cover "the whole of chemistry in its scientific aspects." The arrangement of sections and material within a section is distinctly different from that in Chemical Abstracts. The

[1] For a very good discussion of the 1925–29 cumulative index and the subject of classification in indexes see Crane, *J.Chem.Education* **10,** 448 (1933).

A long discussion of the Zentralblatt was published by Dammon in the *Z.angew.Chem.*, **25,** 1614–23 (1912). Other material will be found in the following references: Pflücke, *Ber.*, **62A,** 132 ff. (1929); Willstätter, *Z.angew. Chem.*, **42,** 1049–52 (1929).

abstracts are good, reasonably complete, and prompt. There are practically no patent references or new book entries.

Part B is considered, in some respects, the best abstract journal available for technical subjects. It is, however, somewhat restricted as to the field covered. The English and United States patent abstracts are very good. New books are not mentioned.

Article journals containing abstracts

Bulletin de la Société Chimique de France.[1] La Société Chimique de France, Paris, 1858– . Abstracts were started in 1863 following combination of the Bulletin with the Répertoire de chimie pure et appliquée. The section on applied chemistry was issued separately as before. Down to 1892 the "Memoirs" and "Travaux" (abstracts) were published together and paged continuously. Then the abstracts of foreign papers were segregated and issued in a separate, even-numbered volume each year until 1920. Since then the "Memoirs" have been published in the odd-numbered volume for each year, and all abstracts, both French and foreign, have been in the even-numbered volume. Individual issues appear monthly. They contain the memoirs and abstracts which are bound separately later.

Indexes:

Annual—1863 Author only
1864– Author and subject

Cumulative—Author and subject for each of the following periods: 1858–74, 1875–88, 1889–98, 1899–1906, 1907–16, 1917–26

(Note that memoirs and abstracts are indexed together.)

The field of pure chemistry is incompletely covered. The abstracts are accurate and full but are not used very extensively in this country.

Chimie & Industrie. Société de Chimie Industrielle, Paris, 1918– . Published monthly.

Indexes:

Annual—Author, subject, new books, patents (started with Vol. 23, 1930)

[1] *De Paris* before 1907.

Each issue has four divisions. The paging is consecutive for a volume, and in addition each division is paged separately; i.e., every page carries two numbers; the first refers to the whole volume, and the second, consisting of a number and a letter (123 D), indicates the page within the division. Index references give both numbers. There was one volume in 1918 and one in 1919; since then there have been two each year. Volumes 1 to 18 (1918–27) have a subject index for each division, placed at the front of the book; in Vols. 19 to 22 the index is at the back. The essential parts are the same in both cases. Starting with Vol. 23 (1930) there has been but one subject index, a combination of those previously issued plus a rather extensive patent-number section.

Each issue of Chimie & Industrie contains a few articles which occupy less than half of the space. The balance is devoted to abstracts. These are good but somewhat tardy. This journal is probably the best source of information regarding French patents. All abstracts have a decimal classification number.

Journal of the Chemical Society. The Chemical Society, London, 1841– . Published monthly between the twentieth and the twenty-fifth. The publication of abstracts started in 1871 (Vol. 24 or, N.S., Vol. 9), ceased in 1925. Abstracts were paged and indexed with the articles from 1871 to 1877 (Vol. 32). Starting in 1878 and continuing down to 1925 the journal published two volumes each year, the even-numbered volume being "Abstracts." Beginning in 1893 and continuing to 1925 the abstracts volume was divided into two parts: Part I was devoted to Organic, Physiological, and Agricultural Chemistry; Part II contained General and Physical Chemistry.

Indexes: (1882–1925)

- Annual—Author and subject. In Vols. 24–32 there is only one index for both articles and abstracts; subsequently the latter have been indexed separately
- Cumulative—Author, subject, corrections, and additions for each of the following periods: 1873–82, 1883–92, 1893–1902, 1903–12, 1913–22

As indicated in the discussion of British Chemical Abstracts, Part A, the summaries appearing in the Journal of the Chemical

Society are concerned chiefly with pure chemistry. They are sufficiently complete and uniformly well prepared.[1]

Journal of the Society of Chemical Industry. The Society of Chemical Industry, London, 1882– . Now published weekly on Friday as "Chemistry and Industry." Paged consecutively with other material down to 1918. Starting with Vol. 37 the journal was, and still is, divided into three parts: Review (R), Transactions (T), and Abstracts (A), each paged separately, the page numbers being accompanied by the appropriate letter as indicated. The intention, when making this change, was to have the abstracts division appear in alternate issues. Down to 1937, however, the output was so large that almost every number contained some abstracts. Then the policy was adopted of publishing a separate abstracts section at the end of each month, thus conforming with the Part A system.

Indexes:
- Annual—Author, subject, patent, and errata. A list of the journals covered is included
- Cumulative—Author and subject, also errors for the periods 1882–95 and 1896–1905

In many respects this is considered the best abstract journal for technical subjects. In the past its field has been limited. The patent literature has been well covered.

Zeitschrift für angewandte Chemie. Verein Deutscher Chemiker, E.V., Berlin, 1888– . Published weekly on Saturday as "Angewandte Chemie" the name having been changed in 1932.

Indexes:
- Annual—Author, subject, and patent; also corrections
- Cumulative—Author, subject, and patent for the periods 1887–1907 and 1908–27

Before 1919 the Chemisches Zentralblatt published very few abstracts of technical articles. Hence anyone wishing such material should refer to Angewandte Chemie, which appeared

[1] The abstract of an article on bivalent carbon by J.U. Nef occupies nine pages [*J.Chem.Soc.*, **74**, I, 102 (1898)]. This is the longest abstract that the writer has encountered.

in one volume 1888–1903, in one volume of two parts 1904–12, and in three parts 1913–18. Abstracts, patent abstracts, articles, and a commercial news section appeared in each issue consecutively paged throughout the year from 1888 to 1912. During the period 1913–18 one volume of three separately paged parts was issued. The index for each of these years (1913–18) is in Part I.

Abstracts in special fields

There are many journals, including trade organs, devoted to special phases of chemistry. Some of these publications contain abstracts of articles pertaining to the field considered. No attempt will be made here to give a complete list of such journals, the object being to indicate the variety available.

Analyst. 1887– . Few abstracts are to be found in the early issues.

Annales de chimie analytique et de chimie appliquée et revue de chimie analytique. Series I, Vols. 1 to 23, 1896–1918; Series II, Vol. 1 to , 1919– . The Revue was absorbed in 1898.

Experiment Station Record. 1889– . Devoted exclusively to the various phases of agriculture. There are indexes covering the periods 1889–1901, 1901–11.

Journal of the Iron and Steel Institute. 1871– . "Abstracts of all articles on the foreign iron, steel, and allied industries."

Journal of the Society of Dyers and Colourists. 1884– .

Kolloid-Zeitschrift. 1906– .

Zeitschrift für analytische Chemie. 1862– . There is a cumulated index for every 10 volumes.

Journal of the American Leather Chemists' Association. 1906– .

Abstracts in related fields

Biological Abstracts. 1926– . Covers theoretical and applied biology.

Physiological Abstracts. 1916– . Covers plant and animal physiology and biochemistry.

Science Abstracts A. 1903– . Physics.

Agricultural Index. 1916– .

Engineering Index (New York). 1906– .

Index medicus. 1879– . During the period 1899–1902 this index was published in France as *Bibliographia Medica.*

Industrial Arts Index. 1913– . Published monthly and cumulated in full quarterly, yearly, and biennially.

Repertorium der technischen Journal-Literatur. 1823–1908.

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Mellon, pp. 71–81.

Dammann, *Z.angew.Chem.*, **25**, 1614–23 (1912). Discusses the organization of chemical literature.

Miller, *Ind.Eng.Chem.*, **6**, 411–15 (1914). Discusses the centralization of abstracting service.

Patterson and Curran, *J.Am.Chem.Soc.*, **39**, 1623–38 (1917). A discussion of the system of organic nomenclature used in the decennial index of Chemical Abstracts. More recent articles on organic nomenclature have been published by Patterson.

Crane, *Ind.Eng.Chem.*, **14**, 900–4 (1922). Discusses indexes, how to make and use them.

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Prager, *Z.angew.Chem.*, **42**, 1055–9 (1929). The nomenclature of organic chemistry.

Willstätter, *ibid.*, **42**, 1049–52 (1929). The hundredth birthday of the Zentralblatt.

Speter, *Chem.Weekblad*, **27**, 560–2 (1930). *Wie man nicht referieren soll und darf.* Speter believes that the French abstracts are the best.

REVIEW AND MONOGRAPH SERIES

"Too many diligent investigators spend valuable time and effort rediscovering facts recorded years before."

REVIEWS

A review is a survey of the literature published during a certain period. It may be a critical evaluation of the ideas advanced and their supporting data or merely a summary. Often the field is limited not only as to time but also as to subject matter, country, and author. Reviews may appear as short articles, monographs, or books. When an element of relationship enters, the group thus connected usually is called a "review series."[1] Typical examples are the annual reports, yearbooks, Fortschrittsberichte.

History

Historically considered, reviews have exercised an influence on the advance of chemistry second only to that of the abstract journals. Soon after the establishment of Crell's journal, scientists realized that something more was needed; but it was not until 1795 that the first review series was started, viz., the "Berlinisches Jahrbuch der Pharmacie." A few years later (1821) Berzelius founded his Jahresbericht in which he undertook to survey critically the scientific advances of each year. His work was so important that it appeared in Swedish and in German. As the years passed similar journals were founded, but with the rapid increase in chemical knowledge it soon became impossible for any one man adequately to survey the entire field. Annals were established, each devoted to one aspect of chemistry, e.g., organic. Later, specialists were required for the various phases of a division. With the diversification of effort the older type of review lost its prominent position so that today there are only a few outstanding survey

[1] A "series" has been defined as "a number of books published in the same style, each of which is complete in itself, but all of which have some common point of interest."

series, but review articles will be found in a number of journals and monograph series (see Table 13). Among the more important yearbooks are the "Annual Reports of the Chemical Society," the "Report of Progress of Applied Chemistry" of

TABLE 13.—PERIODICALS FREQUENTLY PUBLISHING REVIEWS

Title	Date started	Remarks
Chemical Reviews	1924	Issued quarterly. Has collective author and subject indexes for Vols. 1–10.
Fortschritte der Chemie, Physik, und physikalische Chemie.	1909	Critical reviews. Has collective index for Vol. 1–5, 6–16.
Annales de Chimie	1789	Contains comprehensive papers summarizing the author's own work previously published elsewhere as progress reports.
Annales de Physique	1789	Contains comprehensive papers summarizing the author's own work previously published elsewhere as progress reports.
Kolloid Beihefte	1909	Contains comprehensive papers summarizing the author's own work previously published elsewhere as progress reports.
Angewandte Chemie	1888	See indexes under "Fortschrittsberichte."
Chemiker Zeitung	1877	See indexes under "Fortschrittsberichte."
Zeitschrift für Elektrochemie	1894	
Chemical and Metallurgical Engineering	1902	See especially the January number.
Industrial and Engineering Chemistry	1909	See especially the September issue.

the Society of Chemical Industry, the "Mineral Industry," and the "Annual Survey of American Chemistry," to mention only a few of more general interest (cf. Table 15). All four are excellent, but there is at least one serious impediment to their use: The individual articles are not mentioned in the abstract

journals. Normally the demand is for a review on a particular topic for a certain period. A search of the subject indexes reveals nothing. Consequently the only way to find a desired review is to examine the individual series. At first this may seem tedious, but with a little experience one soon becomes familiar with the type of review appearing in any given series as well as the authors and various indexes. For example, there are collective indexes to the first 20 volumes of Chemical Reviews; the summaries in Angewandte Chemie are all listed in the annual subject indexes under "Fortschrittsberichte"; certain men have been writing the reviews in the Annual Reports for many years. Of course one might prepare a subject index of the reviews in his field. Once assembled on cards there would be practically no trouble in keeping it up to date.

Quality

The quality of a review depends almost entirely upon the knowledge and judgment of its author. A good reviewer must be an expert in the field covered, therefore is able to express a reliable opinion about the worth of any contribution in that division. He is unbiased, hence endeavors to show the relative position of each article and the general trend of research activities. Furthermore, if selection is necessary, he chooses the important material and does not give a distorted impression of the state of affairs by omitting valuable data or placing undue emphasis on minor issues. Finally he includes references to all articles mentioned.

Usefulness

The usefulness of a review is apparent to a busy chemist who must keep abreast of the advances in fields allied to his own. A review series, for him, is distinctly superior to an abstract journal because the abstracts are non-critical, unorganized, and only superficially classified. On the other hand, it is the purpose of a review to evaluate and coordinate the articles considered. Of course the abstract of a given paper is generally longer than the review. The difference is of minor significance here because the reader is particularly interested in the features just mentioned and the problem actually faced, i.e., whether

he must spend the time required to prepare a desired summary or can utilize the work of others. This same point frequently arises in another way. A review, except for arrangement, is

TABLE 14.—SUMMARY OF REVIEWS APPEARING IN THE ANNUAL REPORTS OF THE CHEMICAL SOCIETY

Subject	In Reports
Agricultural chemistry	1904–23
Analytical chemistry	1904–
Biochemistry	1924–
Catalysis	1928
Colloids	1924, 1925, 1931
Crystallography	1908, 1917, 1919–29, 1931, 1933, 1935
General and physical chemistry	1904–
Geochemistry	1930, 1932
Inorganic chemistry	1904–
Kinetics	1927
Mineralogical chemistry	1904–7, 1909, 1915, 1917, 1921–29 (odd-numbered years only)
Molecular structure	1931
Organic chemistry	1904–
Photo-chemistry	1925 (covers period 1914–25)
Physiological chemistry	1904–23
Radio-activity	1904–14 (except 1908), 1916–32 (even-numbered years only), 1933–
Solutions, electrical conductivity	1930
Spectroscopy	1926
Stereo-chemistry	1904–09 (except 1908)
Subatomic phenomena	1922–32 (even-numbered years only) 1933–

practically an annotated bibliography. When such a compilation is needed it may often be obtained quickly and easily by using a review as a basis and merely bringing it down to date. A beginner too frequently presumes that the only way to assemble a bibliography is to start and end with the abstract journals, but with a little experience in locating reviews and other sources he learns that devotion to an abstract journal may be a sheer waste of time. It may be well to repeat the statement that reviews cannot always be found by searching the abstract journals. Many very good reviews are not mentioned in Chemical Abstracts or the Zentralblatt. A tyro may conclude that they do not exist or, if a little more advanced, that it will take more time to find a particular review than to collect the

TABLE 15.—YEARBOOKS

Date	Title	Remarks
1795–1840	Berlinisches Jahrbuch der Pharmacie	Title altered several times
1811–1833	Jahrbuch der Chemie und Physik	Vols. 1–30 published as Beiträge; Vols. 31–60 also issued as Jahrbuch der Chemie . . . ; Vols. 61–9 also appeared as Neues Jahrbuch . . . ; finally united with J. für technische und oekonomische Chemie to form the J. prakt. Chem.
1822–1851	Jahresbericht über die Fortschritte der Chemie und Mineralogie (Tübingen)	A translation of Sec. 3 of Berzelius "Svenska vetenskaps kademien arsberaettelser." There is an index to Vols. 1–25
1847–1910	Jahresbericht über die Fortschritte der Chemie und verwandter Theile anderer Wissenschaften	Liebig und Kopp (Giessen). Title varied. There were two divisions: Inorganic and Organic. Decennial indexes except that the last few are for shorter periods
1855–	Jahresbericht über die Fortschritte der chemischen Technologie	Wagner (Leipzig). Name changed several times. The present name is "Jahresbericht über die Leistungen der chemischen Technologie, mit besonderer Berücksichtigung der Elektrochemie und Gewerbestatistik." Decennial indexes for Vols. 1–50; also patent index 1878–1924, 1925–35. Now in two parts: Inorganic and Organic. The summaries are in the nature of abstracts. There is an author, subject, and patent index for each part. The organic section contains a new book list and statistical tables, both indexed
1858–	Jahresbericht für Agrikultur-Chemie (Berlin)	Name varies slightly. Vol. 66 for 1923 issued in 1926; cumulative indexes for Vols. 1–20 and 21–40

TABLE 15.—YEARBOOKS.—(*Continued*)

Date	Title	Remarks
1865–1901	Jahrbuch der Erfindungen und Fortschritte auf den Gebieten der Physik und Chemie . . . (Leipzig)	Cumulative indexes for Vols. 1–5, 6–9, 10–11, 12–24
1871–1919	Jahresbericht über die Fortschritte der Tier-Chemie, oder der physiologischen und pathologischen Chemie (Wiesbaden)	Subtitle varies. Superseded by Jahresbericht über der gesamte Physiologie. . . . Decennial indexes for Vols. 1–40 (1871–1909)
1873–1881	Jahresbericht über die Fortschritte auf dem Gebiete der reinen Chemie (Tübingen)	
1878–1905	Technisch-chemisches Jahrbuch	Biedermann. Covered the general field of industrial chemistry. Vols. 1–3 issued as supplements to the Chemiker-Kalender
1883–	Mineral resources of the United States	Issued by the U.S. Geological Survey to 1924, subsequently by the Bureau of Mines
1891–1918	Jahrbuch der Chemie	Richard Meyer (Braunschweig). "Bericht über die neuesten und wichtigsten Fortschritte der reinen und angewandten Chemie." Decennial index for Vols. 1–10. Contains rather full and somewhat critical reviews of the most important articles and books appearing during the year. Each section is by an authority; e.g., in Vol. 1 Walther Nernst contributed the material on physical chemistry
1892–	Mineral Industry	Its statistics, technology, and trade. "The object . . . is to bring together as complete a record as possible of the year's progress in the mining and metallurgical industries. It is

Table 15.—Yearbooks.—(*Continued*)

Date	Title	Remarks
		not intended simply as a compilation of production statistics." Scope international. Subjects are alphabetically arranged. Published by McGraw-Hill Book Co.
1892–	Deutscher Färbenkalender	
1894–1909	Jahrbuch der Elektrochemie und angewandte physikalischen Chemie	Nernst and Borchers (Halle a.S.) Abstracts classified under about 20 subjects
1899–1918	Répertoire générale de chimie pure et appliquée	
1904–	Annual Reports of the Chemical Society	Table 14. Only the more important contributions are cited. International in scope
1907–1932	Jahrbuch der organischen Chemie	Schmidt (Stuttgart). Each volume contains a general part, then special divisions, and finally an appendix of (1) literature bibliography (chiefly books), (2) deaths during the year of outstanding organic chemists, (3) author index, (4) subject index
1907–	Science Progress	An English quarterly publication covering various fields of science
1909–1924	Jahrbuch der Radioaktivität und Elektronik (Leipzig)	Merged with Physikalische Zeitschrift after Vol. 20, Pt. 4
1916–	Applied Chemistry Reports (of the Soc.Ch.Ind.)	Arranged same as B.C.A., Sec. B. International in scope
1922–	Chemie-Büchlein. Ein Jahrbuch der Chemie	K.H. Bauer, editor
1922–	Jahresbericht der chemisch-technischen Reichsanstalt	Verlag Chemie. Vol. 4 for 1924–25 issued in 1926
1926–1935	Survey of American Chemistry	National Research Council. "In general the articles have been drawn up to cover the fundamental subjects of present day interest." Both pure and applied chemistry are included

TABLE 15.—YEARBOOKS.—(*Continued*)

Date	Title	Remarks
1927–33(?)	Standards Yearbook	U.S. Bureau of Standards
1927–	Vom Wasser. Ein Jahrbuch für Wasserchemie und Wasserreinigungstechnik	Published by Verein deutscher Chemiker
1931–	British Plastics Year Book	"The handbook and guide to the plastics industry, published by Plastics Press, London. There are eight sections among them being a list of producers, world plastics journals, trade names, and a "Who's Who"
1932–	Annual Review of Biochemistry	Published by Stanford University Press. "The Annual Review . . . will present from year to year reviews of the current developments in from twenty-five to thirty of the major fields of interest"

For additional reviews see:
GREGORY, Union List of Serials.
CRANE and PATTERSON, *op. cit.*, pp. 135–6.
National Research Council. Vol. 1, No. 3. Periodical Bibliographies and Abstracts for the Scientific and Technological Journals of the World.
BOLTON, Bibliography of Chemistry.

references one by one. In order to familiarize the beginner with some of the important sources Tables 13 to 15 have been compiled. The first lists a few of the periodicals frequently publishing reviews; the second is an index of the subjects treated in the "Annual Reports of the Chemical Society"; the last attempts to give some notion of the number and variety of annual surveys that are available.

MONOGRAPHS

The term "monograph" is not easily defined when applied to chemical literature because it normally carries three implications: length, breadth of subject, and connection with other reports, any or all of which may be ignored in a particular instance. A monograph is supposed to be longer than an "article" and yet

short enough to be bound in one cover. In subject matter a monograph is usually restricted to a comparatively narrow field which is considered in some detail. Frequently the objective is to present a survey of present knowledge on a chosen topic, to coordinate or comprehensively summarize work recently published.

Series

The relationship of a monograph to other books may be close or distant. In the former case the group is often called a "monograph series." Such a collection may be united topically ("Monographs on Applied Electro-chemistry"); by editorial guidance (Ahrens' "Sammlung"); or through sponsorship by a learned society, a publisher, or an institution (see Table 16). It is often very difficult to distinguish between a monograph series, "Manual" series, "Handbuch," and "Symposium" report. The terms, as used, are frequently synonymous. Incidentally it should be noted that the Germans, in addition to the term "Monographie," often use other words such as "Einzelarbeit," "Einzelaufnahme," "Einzelschrift," "Einzeldarstellung," "Einzelheft," and "Ergebnisse."

Reliability

A preliminary notion of the reliability of an individual monograph or series may often be gained from the standing of the editor, sponsor, and author. The bibliography is also an important feature. It should be reasonably up-to-date and contain references to all of the important literature. Completeness, however, is not absolutely essential. The inclusion of every paper on a subject may suggest a lack of discrimination, a mere cataloging of articles without indicating their relative merits. Since a monograph is read for purposes of orientation, the unbiased judgment of the writer should be its most valuable asset, it being assumed, of course, that he has the necessary background to make his opinion authoritative.

Searching for a monograph

Finding a monograph is simple or difficult depending upon its nature and the amount of information at hand, since it may

TABLE 16.—MONOGRAPH SERIES

Publisher	Series title and editor	Started	Remarks
Akademische Verlagsgesellschaft, Leipzig.	Ergebnisse der angewandte physikalische Chemie, M. LeBlanc	1931	Vol. 4 (1936) deals with water and sewage
Akademische Verlagsgesellschaft, Leipzig.	Handbuch der allgemeinen Chemie, Ostwald and Drucker	1918	Vol. 9 (1937), Fricke and Hüttig, "Hydroxides and Oxide Hydrates"
Akademische Verlagsgesellschaft, Leipzig.	Hand- und Jahrbuch der chemischen Physik, Eucken and Wolf	—	To be 12 vols.
Akademische Verlagsgesellschaft, Leipzig.	Physik und Chemie in ihre Anwendung in Einzeldarstellung		Two issues in 1936 were Klemm, "Magnetochemie"; Weizsäcker, "Atomkerne"
American Chemical Society, Washington (cf. Reinhold).	Chemical Reviews, G. Wendt	1924	There is a subject and author index for Vols. 1–10
Baillière, Tindall & Cox, London.	Industrial Chemical Series, Barnett	1921	Comprehensive surveys of the chemical industries. There were 18 titles by 1936
Barth, J.A., Leipzig.	Handbuch der angewandte physikalische Chemie in Einzeldarstellung, G. Bredig	1905	Eminent authors, such as Paul Walden and F. Foerster, have contributed to this series
Blackie & Son, London.	Manuals of Pure and Applied Chemistry, R.M. Caven	1928	Five titles by 1933
Cambridge University Press, Cambridge, England.	Cambridge Series of Physical Chemistry, E.K. Rideal		Two recent titles are Kronig, "Optical Basis of the Theory of Valency" (1935); and Farkas, "Orthohydrogen, Parahydrogen and Heavy Hydrogen." (1935)
Chapman and Hall, London.	Monographs on Applied Chemistry, E.H. Tripp	1928	Vol. 9 (1935) Glasstone and Hickling, "Electrolytic Oxidation and Reduction . . ."

TABLE 16.—MONOGRAPH SERIES.—(*Continued*)

Publisher	Series title and editor	Started	Remarks
Chemical Catalog Co. (See Reinhold).			
Constable & Co., London.	Outlines of Industrial Chemistry, G.D. Bengough	1920	
Cornell University Press, Ithaca, N.Y.	George Fisher Baker Non-resident Lectureship in Chemistry	1926	Two recent titles: Hahn, "Applied Radiochemistry"; and Bragg, W.L. "Atomic Structure of Minerals"
Enke, F., Stuttgart. .	Bibliothek für Chemie und Technik, L. Vanino	1931	No. 24. Kausch, "Hydrofluoric Acid, Hydrofluosilicic Acid and Their Metal Salts" (1936)
Enke, F., Stuttgart. .	Die Chemische Analyse, Wm. Böttger	1907	Every investigator in analytical chemistry should be familiar with this series. No. 37. Prodinger, "Organic Precipitating Agents in Quantitative Analysis" (1937)
Enke, F., Stuttgart. .	Sammlung chemischer und chemisch-technischer Vorträge, F.B. Ahrens	1896	An outstanding series. No. 36. Wohryzek, "Activated Decolorizing Charcoal" (1936). No. 37. Briegleb, "Intermolecular Forces and Molecular Structure" (1937)
Gurney and Jackson, London.	Transactions of the Faraday Society	1903	One or two "General Discussions" or symposia are published each year. The sixty-fifth appeared in January, 1937

TABLE 16.—MONOGRAPH SERIES.—(*Continued*)

Publisher	Series title and editor	Started	Remarks
Hartleben, A., Vienna.	Chemisch-technische Bibliothek		No. 402. Winkler and Rich, "Spiegelfabrikation" (1936)
Hermann & Cie., Paris.	Actualités scientifiques et industrielles		There were several divisions containing over 500 titles by 1937
Hirzel, S., Leipzig...	Chemie und Technik der Gegenwart, W. Roth	1923	
Hirzel, S., Leipzig...	Leipziger Vorträge, Paul Debye	1930	
Knapp, W., Halle	Monographien über angewandte Elektrochemie, V. Engelhardt	1902	Vol. 52 was published in 1933
Knapp, W., Halle	Monographien über chemisch-technische Fabrikationsmethoden, L.M. Wohlgemuth	1906	No. 57. Klar, "Manufacture of Absolute Alcohol for Use in Motor Fuels" (1936)
Lockwood, Crosby and Son, London.	Manuals of Chemical Technology, Geoffrey Martin	1916	
Longmans, Green & Co., New York.	Monographs on Biochemistry, Plimmer and Hopkins	1910	The famous Plimmer series
Longmans, Green & Co., New York.	Monographs on Industrial Chemistry, Sir Edward Thorpe	1920	There were 14 titles by 1936
Reinhold Publishing Corp., New York, N.Y. (Successor to the Chemical Catalog Co.)	American Chemical Society Monograph Series, W.A. Noyes and H.E. Howe	1918	Scientific and technological. No. 73. Egloff, "Reactions of Pure Hydrocarbons" (1937)
Reinhold Publishing Corp., New York, N.Y. (Successor to the Chemical Catalog Co.)	Colloid Symposium Monographs, H.B. Weiser	1923	The National Research Council has published an index to Vols. 1–10

TABLE 16.—MONOGRAPH SERIES.—(*Continued*)

Publisher	Series title and editor	Started	Remarks
Spamer, O., Leipzig	Chemische Technology in Einzeldarstellung	1926	There are two series: "Spezielle chemische Technologie" and "Allgemeine chemische Technologie"
Steinkopf, T., Dresden.	Technische Fortschrittsberichte. Fortschritte der chemischen Technologie in Einzeldarstellungen, B. Rassow	1923	No. 39. Durrer, "Erzeugg. v. Eisen u. Stahl" (1936)
Steinkopf, T., Dresden.	Wissenschaftliche Forschungsberichte. Naturwissenschaftliche Reihe, R.E. Liesegang	1921	Not exclusively chemical. Vol. 42 appeared in 1936; Vol. 41, in 1937
Vieweg, F., und Sohn, Braunschweig.	Handbuch der chemischen Technologie, Bolley	1862	This famous "Bolley's Technology" is entered here because of its importance historically
Wissenschaftliche Verlagsgesellschaft (Initially F. Enke, Stuttgart).	Chemie in Einzeldarstellungen, J. Schmidt	1912	No. 17. Schmidt, "Organo-metallic Compounds" (1934) (cf. p. 157)

be bound separately or together with other papers. With respect to the former, if the author and the approximate date of publication are known, author indexes of the abstract journals should be helpful, as should also the "United States Catalog" and foreign book lists of the same nature. If the treatise is owned by the local library, the card catalog may have an author entry. The book, however, may be one of a series. Individual author cards are then frequently omitted, and one entry for the whole group is placed under the editor's name, especially if he is well known. When the title or merely the subject is available the subject indexes of the abstract journals and the title and subject cards in the catalog should be examined. Here, again, the

search is more likely to be successful if the series title is known because in a library catalog all issues of a series are entered under the series name in volume-number order. If a German publisher has issued the series, the "Deutsches Bücherverzeichnis" will contain, under the series title, a complete list of the monographs published during the period covered. In addition there will be the author's name, date of publication, size, and price. Occasionally the catalog of an English or American publisher will contain lists of his monograph series, but the date of publication is seldom included. Finally, if a book of the series is available, usually in the front or back advertising section a list will be found of all monographs in the series together with the author, title, price, etc. Often books "in preparation" are also mentioned.

The search for a monograph forming only part of a book is, in general, the same as that just outlined except that the library catalog is very likely to be of less service. Owing to the difficulties encountered by many students in locating these shorter monographs a rather detailed list of sources has been included in Table 16 which, with the references given, should be of material assistance. This type of literature is too valuable to be ignored just because it cannot be readily found.

Symposia articles

Strictly speaking, a symposium is a collection of comments or opinions, a group of brief articles on the same, or different, aspects of a subject. Frequently both reviews and monographs are involved. Sometimes the subject is comprehensive (Colloid Symposia); frequently it is restricted to a small field (Dipole Moment). In any case it is not difficult to find the published papers, because they are treated as new material by the abstract journals. Incidentally, many symposia have been sponsored by the Faraday Society, and the papers have been published in the Transactions. The American journal Industrial and Engineering Chemistry has also given space to several symposia during the past few years.

CHEMICAL DICTIONARIES AND ENCYCLOPEDIAS

"Few people ask from books what books can give. . . ."
VIRGINIA WOOLF

The primary function of a dictionary is to define words and to give their meaning, pronunciation, usage, etc. An encyclopedia describes things. If this distinction is applied it soon becomes evident that many books entitled "Dictionary . . ." are slightly to almost wholly encyclopedic in nature. For example, Hackh's "Dictionary of Chemistry" is devoted principally to definitions, but frequently descriptive passages are found such as that on the Lewis-Langmuir theory (pp. 423–4 of the first edition). At the other extreme Thorpe's "Dictionary of Applied Chemistry" is concerned largely with descriptions of materials and processes, hence should be classed as an encyclopedia. In the following discussion, attention will be directed first to the descriptive books and then to those that are chiefly dictionaries regardless of titles. Furthermore, although they do contain many articles of chemical interest, the more general reference works will not be considered.[1]

Purpose

Probably one of the most important functions of an encyclopedia is to serve as the basis for a comprehensive literature search. The articles, usually written by experts, contain authoritative summaries of our knowledge down to the time of writing. They reveal the status of the subject without bias and thus help an investigator to secure orientation and perspective. In addition, the bibliographies are guides to the more important

[1] Incidentally the Italian encyclopedia "Enciclopedia Italiana di Scienze, Lettere ed Arti," Istituto Giovanni Treccani, Roma, 1929– (Vol. 32, 1936) is one of the best in quality and number of illustrations. All articles are signed. There are many good bibliographies, biographies of living persons, and portraits. Professor Parravano is editor of the articles dealing with chemistry.

original sources and represent library work already done which it should be unnecessary to repeat.

Use

When consulting an encyclopedia for the first time, always read the preface or introduction for information regarding the object, scope, and arrangement of the work. Special aids should be noted. Even though the entries are in alphabetical order, many encyclopedias have an index in each volume and a cumulated index in the last number. This feature is of value for cross references and location of subject matter not revealed by article titles. Possibly there are corrections, addenda, or supplementary volumes. If so they will require examination for relevant data. Since encyclopedias are often issued serially, the date of any section consulted is of importance. If abbreviations are used the key to their meaning should be located. Finally, the publication of a good encyclopedia is very expensive, calling for experienced writers and able editorial supervision. Consequently the reputation of the publisher and editorial staff in addition to that of the authors of the various subdivisions should be indicative of the worth of the whole compilation. The essential points, therefore, in determining the standing and usefulness of an encyclopedia, or any other reference book, are (*a*) authority of the data, including accuracy, completeness, and age; (*b*) bibliography (none, full, well selected); (*c*) mechanical arrangement; and (*d*) the group responsible for its production.

BIBLIOGRAPHY

Encyclopedias

A. Predominantly pure chemistry

Frémy, M.E. (ed.), "Encyclopédie chimique," H. Dunod, Paris, 10 "tomes" plus an index, 94 vols., 1882–99. The following topics are included:

I. History of chemistry with a brief biography of each of about thirty-five chemists.
Summaries of advances in various fields of chemistry.
Selected topics in physical chemistry.
Description of various European laboratories.

II. Inorganic chemistry, metalloids.
III. Inorganic chemistry, metals.
IV. Inorganic analysis.
V. Applications of inorganic chemistry.
VI–X. Organic chemistry.

A table of contents for each volume is given in Vol. 94, pp. VI–VIII.

This is an elaborate work but chiefly of historical value.

Ladenburg, A. (ed.), "Handwörterbuch der Chemie," Eduard Trewendt, Breslau, 13 vols. and a table of contents, 1882–95. This work covers pure chemistry including theoretical and physical. It is said to be very good for historical material. There is an extensive bibliography at the beginning of each division. All articles are signed. Each volume has an index and list of errors. The "Vorwort" in Vol. I should be consulted for arrangement and nomenclature.

"Watts' Dictionary of Chemistry," Longmans, Green & Co., New York, 4 vols., 1888–94. Apparently this revised edition has been reprinted twice, the first time in 1898–1901, and the second time in 1918–27.

The first edition of this book, published in 1863–7, was edited by Watts and bore the title "Dictionary of Chemistry and the Allied Branches of Other Sciences. Founded on that of the late Dr. Ure." It devoted considerable space to chemical technology. The last edition was prepared by H. F. Morley (organic section) and M. M. P. Muir (general and inorganic sections) who restricted the discussion to pure chemistry, especially the application of physical methods (see the special article "Physical Methods Used in Chemistry"). Except for the division entitled "Analysis" little or no attention is given to details of analytical chemistry. There are, however, certain exceptions such as the section on arsenic. Considerable space is devoted to important theories and principles, also to general surveys, e.g., "Alkali Metals," "Carbon Group of Elements," "Oxides," "Hydroxides," "Hydrates," and "Amines."

The general arrangement is alphabetical, but the subject headings are not altogether consistent especially where inversion is possible. The following are to be found under the letter underscored: "Composition, chemical"; "Chemical change";

"Equilibrium, chemical," "Metals, rare"; "Noble metals." There is no index, but the introduction to each part gives an explanation of the plan of assembly. In the inorganic section the elements are described in alphabetical order. After each element its binary compounds are listed. All other salts are discussed under the appropriate acid radical. There are also special articles on the alums and other salt groups of importance. Addenda to the inorganic subjects will be found in Vol. IV.

The plan, in the organic division, is to treat each compound separately covering physical properties, preparation, purification, and main reactions. Many special sections have been introduced such as "Azo compounds," "Ammonia derivatives of benzaldehyde," "Organic derivatives of Sb, As, and Bi," and "Action of aluminum chloride."

This book is old, but the recent reprinting is proof that in many respects it is still very valuable not only because it gives a good summary of each subject but also for the many references to be found scattered throughout the text.

B. Chiefly applied chemistry

Dammar, O., "Chemische Technologie der Neuzeit," F. Enke, Stuttgart, 2d ed., 5 vols., 1925–32. This edition was prepared by Peters and Grossman. The entries are very brief. [Cf. review by Olin, *Ind.Eng.Chem.*, *News Ed.*, **12,** 131 (1934).]

Muspratt, J.S., "Encyklopädisches Handbuch der Technischen Chemie," F. Vieweg und Sohn, Braunschweig, 4th ed., 11 vols. plus 5 supplements and a general index, 1888–1922. The first edition, in English, was written by Muspratt and published as two volumes in 1854–62. It was entitled "Theoretical, Practical, and Analytical Chemistry in Use in Art and Trade. Encyclopedic Handbook of Applied Chemistry." The fourth edition, in German, was begun by Stohmann and Kerl; the supplements were completed by Neumann, Binz, and Hayduck. Volumes 1 to 8 were published between 1888 and 1905, the others as indicated in Table 17.

The topics are arranged alphabetically. Each volume has a good table of contents, and there is a separate volume containing an index to the entire set. Some of the topics are exhaustively

treated; e.g., Vol. 11 contains over 625 pages on water, covering almost every phase of the subject from sampling and analysis to the installation of a municipal filtration plant. The section on zinc in Vol. 9 occupies about 900 pages and includes everything from the history of zinc to its zirconium alloys. In all cases many references to original sources are inserted as footnotes. When using the book it should be noted that columns, not pages, are numbered. All extensive entries conclude with the compiler's name.

TABLE 17.—MUSPRATT'S "ENCYCLOPEDIA"

Volume	Date	Contents
1–8	1888–1905	A—W
9	1910–21	Wine—Zinc
10	1905–22	Tin—Sugar
11	1913–17	Water
12	1922	General index
		Supplements
I	1917–21	Fuels, etc., Addenda, Index
		Pt. 1. Asphalt, petroleum waxes, glycerine . . .
		Pt. 2. Coke, explosives, tanning, fireworks . . .
II	1926–7	Chemical technology of inorganic materials, Index
		Pt. 1. Ammonia to Mortar
		Pt. 2. Ozone to Zirconium
III	1915–7	Chemical technology of organic materials, Index
		Pt. 1. Ether, drugs, celluloid, natural dyes . . .
		Pt. 2. Patents, resins, rubber, textiles . . .
IV	1915–22	Chemical technology of fermentation, tanning, foods . . .
		Pt. 1. Alcohol, bread . . .
		Pt. 2. Sugar, saccharin
V	Not published	Metals

THORPE, SIR EDWARD (ed.), "Dictionary of Applied Chemistry," Longmans, Green & Co., New York, 6th ed., 7 vols., 1921-', 3 supplemental vols., edited by Thorpe (J.F.)[1] and

[1] Si Edward Thorpe died Feb. 23, 1925. The last two volumes of the main p rt were edited by H.F. Morley, the supplements by J.F. Thorpe and M.A. Whiteley.

Whiteley, 1934–6. The first volume of the 7th ed. was issued in 1937.

This work is believed to be "a reasonably adequate presentation of the state of contemporary knowledge concerning the applications of chemical science." Though a wide field is covered and the articles are, therefore, brief they do "serve as introductions to the special works on the items discussed. Some of them are practically small monographs." There are a few references, mostly in the text. The initials of the various authors appear at the end of the articles or sections; full names will be found at the beginning of each volume. "Their names and standing are a sufficient guarantee that . . . every effort has been made to make the Dictionary a faithful record of the present relations of chemistry to the arts and sciences."

Among the extensive summaries will be found "Azo dyes," "Triphenylmethane dyes," "Wood distillation," "Synthetic drugs," "Tautomerism," and "Carotenoid pigments." Under "Analysis" in Vol. I (pp. 222–326) are discussed first the dry and wet methods of qualitative analysis, then quantitative procedures for the metals, acids, organic compounds, gases, and other materials. In supplementary Vol. I there is a good review of organic reagents and their use in analysis. The subject "Aluminum" (Vol. I, pp. 156–75; supplementary Vol. I, pp. 57–65) is treated under ten subheadings: occurrence, history, metallurgy, development of the industry, production, physical properties, chemical properties, corrosion, alloys, compounds. Although the arrangement of main entries is alphabetical, in order to assist anyone looking for subtopics, good indexes will be found in Vol. VII and in supplementary Vol. III.

Ullmann, Fritz (ed.), "Enzyklopädie der technischen Chemie," Urban & Schwarzenberg, Berlin, 2d ed., 10 vols. plus an index, 1928–32. "This publication is the latest word in chemical technology . . . the work is well done, carefully edited, and uptodate, so far as such material can be obtained for public distribution."[1]

Ullmann considers not only the heavy chemicals industry and metallurgy but also closely related fields involving minerals,

[1] Parsons, C.L., *Ind.Eng.Chem.*, **21**, 889 (1929).

drugs, foods, and their congeners. Processes and purely theoretical topics are included if of any technical importance.

The articles have been written by specialists whose names appear in a table at the front of each volume. All important discussions carry an extensive bibliography including many references to German patents. Corrections have been furnished on separate sheets to be pasted in at the appropriate places. In addition they have been repeated in a table at the front of the index volume. This book also contains a list of the more important topics in each volume of the text. The many cross references in the index help to locate material not found under the headings first considered.

There are some peculiarities of arrangement. Inorganic salts and oxides are to be found under the element. Substitution derivatives of organic compounds are generally entered under the parent compound, but anilin and benzoic acid, for example, are listed separately, not under benzene. Salts of organic acids are considered under the acid. German trade names for many products are entered such as "blankit" for sodium hydrosulfite, and "formin" for hexamethylene-tetramine (urotropine).

Ure, A., "Dictionary of Chemistry," Longmans, Green & Co., London, 6th ed., 3 vols., 1867–75. One supplement was published in 1878. The edition cited was edited by Robert Hunt under the title "Ure's Dictionary of Arts, Manufactures, and Mines. A Clear Exposition of Their Principles and Practice." The work is now entirely out of date but has some historical interest.

C. Both pure and applied chemistry

Fehling, H.v. (ed.), "Neues Handwörterbuch der Chemie," F. Vieweg und Sohn, Braunschweig, 10 vols., 1871–1930. Shortly before 1840 Liebig, Poggendorff, and Wöhler started to publish their "Handwörterbuch der reinen und angewandten Chemie." The second edition of Vols. I and II was issued by Fehling between 1857 and 1862. Then, in 1871, he began the "Neues Handwörterbuch" intending to include the fields more or less neglected by Watts and Wurtz, i.e., pharmaceuticals and the parts of physics and mineralogy closely related to chemistry.

Fehling edited Vols. 1 to 3; Hell, Vols. 4 to 6; Hell and Häussermann, Vols. 7 to 8; Hell and Bauer, Vol. 9; and Bauer, Vol. 10. The first eight volumes were issued by 1903; Vol. 9 appeared in 1926; Vol. 10 was started in 1927, finished in 1930.

The general arrangement is alphabetical with a good index in every volume (cf. "Vorrede" in Vol. 1). Bromides, chlorides, cyanides, iodides, oxides, thiocyanates, and sulfides are considered in some detail under each metal, but only the general properties of the oxygen salts are given. The latter are discussed more fully in connection with the acid itself. The compounds of metals with organic radicals are listed in a special section. Derivatives of organic compounds are to be found with the parent compound. Ethers of the higher alcohols and salts of the alkaloids are discussed with the parent alcohol or alkaloid.

TABLE 18.—SOME DIVISIONS IN FEHLING'S HANDWÖRTERBUCH

Subject	Volume	Pages	Number of references
Heat	9	498–684	200
Bismuth	9	1021–72	400
Zinc	10	190–296	800
Tin	10	296–587	2,000
Sugar	10	645–847	1,800

In view of the date of any volume, the articles therein are excellent surveys of the subjects covered. Reasonably complete bibliographies are entered as footnotes (see Table 18). There is a list of contributors and a table of errors at the back of each of the first eight volumes. Only contributors are mentioned in the last two volumes.

WURTZ, A. (ed.), "Dictionnaire de chimie pure et appliquée . . . ," Librairie Hachette et Cie, Paris, 1874–8. Originally there were three volumes of two parts each. Later a two-volume supplement was issued (not dated), and subsequently a second supplement by Wurtz and Friedel (7 vols., 1892–1908) brought the total issue to 15 books.

This compilation is, in nature, a combination of Watts and Thorpe. It is now old but good for historical material. When

using the books one should search all three divisions, the original and each of the two supplements. There are numerous references to the original literature.

D. Miscellaneous

Lueger, O., "Lexicon der gesammten Technik und Hilfswissenschaften," Deutsche Verlags-Anstalt, Stuttgart, 3d ed., 7 vols., 1926–31. This edition was edited by E. von Frey.

"Encyclopédie de chimie industrielle et de metallurgie," J.B. Baillière et Fils, Paris, 1893–7. This is a collection of over 25 independent articles. Perhaps "Monograph Series" would be a more appropriate title than the one used.

"Encyclopädie der Elektrochemie," W. Knapp, Halle, 4 vols., 1895.

Vol. I. "Primary Elements" by Carhart.
II. "Theory of Electrolytic Action" by Vogel.
III. "New Electrolytic Methods in Quantitative Analysis" by Classen.
IV. "Secondary Elements" by Schoop.

"Merck's Index," Merck & Co., Rahway, N.J., 4th ed., 1930. "An encyclopedia . . . giving the names and synonyms; sources, origin, or mode of manufacture . . . physical properties, therapeutic uses, etc., of the chemicals and drugs used in chemistry, medicine and the arts."

Dictionaries

Bailey and Bailey, "Etymological Dictionary of Chemistry and Mineralogy," Longmans, Green & Co., New York, 1929. The title is sufficiently descriptive.

Blücher, H., "Auskunftsbuch für die chemische Industrie," Walter de Gruyter Co., Berlin and Leipzig, 14th ed., 2 vols., 1931. This edition was edited by O. Lange. The book contains an alphabetical list of trade names (chiefly German) together with the chemical composition and uses of the material.

Chemical Age, "Chemical Dictionary," Ernest Benn, London, Vol. 1, 1925. Chemical terms are defined.

Couch, J.F., "Dictionary of Chemical Terms," D. Van Nostrand Co., New York, 1920.

Crispin, F.S., "Dictionary of Technical Terms," Bruce Publishing Co., Milwaukee, Wis., 1929. Defines terms used in architecture, chemistry, etc.

Gardner, William, "Chemical Synonyms and Trade Names," D. Van Nostrand Co., New York, 4th ed. 1937. "A dictionary and commercial handbook." It contains brief definitions of over 15,000 terms.

Hackh, I.W.D., "Chemical Dictionary," P. Blakiston's Son & Co., Philadelphia, 2d ed., 1937. This dictionary is distinctly encyclopedic in nature. In addition to defining scientific terms it attempts to explain the laws and theories of chemistry. Brief biographical sketches, with portraits, of many eminent scientists are included. This is an excellent reference book considering its size.

Kingzett, C.T., "Chemical Encyclopedia," D. Van Nostrand Co., New York, 6th ed., 1937. The book contains "a definition of every word peculiar to the science of chemistry."

"Pitman's Technical Dictionary of Engineering and Industrial Science," Sir Isaac Pitman & Sons, London, 5 vols., 1928–32. This compilation is in seven languages: English, French, German, Italian, Portuguese, Russian, and Spanish. It is arranged alphabetically according to the English terms and includes many chemical words and phrases.

"Condensed Chemical Dictionary," Chemical Catalog Co., New York, 2d ed., 1930. Arranged alphabetically by name, the dictionary gives physical properties, uses, sources, grades, method of manufacture, and hazardous nature of a large number of commercial materials.

Maerz and Paul, "A Dictionary of Color," McGraw-Hill Book Co., New York, 1930. This book is essentially a set of 56 plates showing about 7,000 colors with their names, if known. The plates are so arranged that each color may be designated by coordinates in the same way that places are referred to on a map. There is an alphabetical index of names. "For purposes of correspondence or recording of colors the page, row and column number may be used [to] insure exact understanding of the particular color."

RIDGEWAY, R., "Color Standards and Color Nomenclature," The Author, Washington, 1912. An alphabetical list of over 1,100 named colors and samples of over 1,400 shades are given.

Receipt books

This class of literature contains formulas for adhesives, household cleaners, inks, paints, polishes, and a wide variety of other useful materials. Frequently the composition of proprietary articles is given. Owing to variation in purity or strength of ingredients many of the receipts will yield satisfactory products only after some experimentation.

SLOANE, T.O., (ed.), "Henley's Twentieth Century Book of Formulas," Norman W. Henley Publishing Co., New York, 1937. The various editions of this book have been popular for many years.

BENNETT, H., "Chemical Formulary," D. Van Nostrand Co., New York, 3 vols., 1933–6. "A condensed collection of . . . formulae for making thousands of products in all fields of industry." The third volume contains a good index to the set.

"The Pharmaceutical Recipe Book," American Pharmaceutical Assoc., Washington, 2d ed., 1936.

"The National Formulary," American Pharmaceutical Assoc., Washington, 6th ed., 1935.

INORGANIC CHEMISTRY

"The durability and value of an item of information . . . depends entirely upon the previous knowledge, the interests and the occupation of the person by whom it is read." GREGORY

The previous chapters have revealed the general trend in the development of chemical literature. First the investigators themselves were considered (Biography), then their original reports (Journals), next the initial summaries of their articles (Abstracts), followed by the periodic digests (Annual Reviews) and surveys of smaller divisions within a field (Monographs). Finally synopses, as assembled in large compendiums (Encyclopedias), were discussed in the preceding chapter. We now come to the last step in condensation, viz., specialized reference books including textbooks and tables of constants. For the purposes of this discussion it has been deemed best to consider such literature in four divisions corresponding to the major branches of chemistry: inorganic, organic, analytical, and physical. The material will be taken up in the order specified. While a few elementary texts may be mentioned, attention will be directed chiefly to the more advanced treatises and laboratory manuals.

Comprehensive Treatises

"Gmelins Handbuch der anorganischen Chemie," Verlag Chemie, Berlin, 8th ed., 1924– . The first edition of this monumental reference work was published in 1817. The eighth edition, now appearing under the direction of R.J. Meyer,[1] was started in 1924. A total of 22 volumes, averaging 600 pages each, is contemplated (see Table 19). This handbook "promises to be the most elaborate and exhaustive reference work available covering inorganic chemistry." It includes all inorganic compounds ever described and gives references to the original articles

[1] Meyer has published a description of the new edition in *Angew.Chem.*, **37**, 177 (1924).

so that a student can examine the sources for himself and draw his own conclusions as to the validity of any statement. This indicates that the user is assumed to be a mature chemist capable of judging the probable accuracy of an assertion. Beginners

TABLE 19.—ARRANGEMENT OF "GMELINS HANDBUCH DER ANORGANISCHEN CHEMIE"

Volume	System number	Contents
I	1, 2	Noble Gases, Hydrogen
II	3, 4	O, N
III	5, 6, 7, 8	F, Cl, Br, I
IV	9 to 12	S, Se, Te, Po
V	13 to 15	B, C, Si
VI	16 to 19	P, As, Sb, Bi
VII	20, 21	Li, Na
VIII	22 to 25	K, NH_4, Rb, Cs
IX	26 to 31	Be, Mg, Ca, Sr, Ba, Ra
X	32, 33	Zn, Cd
XI	34	Hg
XII	35 to 38	Al, Ga, In, Tl
XIII	39, 40	Rarer Earths, Actinium
XIV	41 to 44	Ti, Zr, Hf, Th
XV	45, 46, 47	Ge, Sn, Pb
XVI	48 to 51	V, Nb, Ta, Protactinium
XVII	52 to 55	Cr, Mo, W, U
XVIII	56 to 58	Mn, Ni, Co
XIX	59	Fe
XX	60 to 62	Cu, Ag, Au
XXI	63 to 67	Ru, Rh, Pd, Os, Ir
XXII	68 to 70	Pt, Masurium, Rhenium

NOTE.—This table is a key to the location of any element or compound described. As the sections appear, slight changes are being made in the number of elements comprising certain volumes, but no variation in the order of consideration has been found. For a list of the divisions published see Table 26.

are likely to be confused by the many data cited which are more or less contradictory.

Anyone interested in using Gmelin efficiently should become familiar with its scope and limitations as set forth in Sec. 1, pp. IX *et seq.* Brief statements will be found there as to the attitude toward analytical, organic, and technical chemistry; physics, mineralogy, geology, and other subject matter not

strictly inorganic chemistry. It will be noted also that theoretical discussions are excluded.

TABLE 20.—OUTLINE OF ARRANGEMENT UNDER ANY INDIVIDUAL ELEMENT IN "GMELINS HANDBUCH DER ANORGANISCHEN CHEMIE"

History
Occurrence
The Element
  Preparation
  Physical properties
    Of the atom
    Of the molecule
    Crystallographic
    Mechanical
      Density, hardness, ductility, etc.
    Thermal
    Optical
    Magnetic
    Electrical
  Electrochemical properties
  Chemical properties
    Reaction with air, water, non-metals, non-metallic compounds, acids, metals, metallic compounds, etc.
  Chemical properties of the ion
    General reactions
    Qualitative detection
    Quantitative analysis
      Gravimetric, volumetric, electrometric, etc.
Compounds of the element with other elements having *lower* system numbers. (Under any particular compound will be found the preparation; physical, electrochemical, and chemical properties; hydrates; properties of its aqueous and non-aqueous solutions)
Hydrides
Oxides (from lowest to highest)
Nitrogen compounds
  Nitrides
  Nitrogen plus oxygen
Fluorine compounds
Chlorine compounds
  Chlorides
  Chlorine plus hydrogen
  Chlorine plus oxygen
  Chlorine plus nitrogen
  Chlorine plus fluorine
Bromine compounds, etc.

In both the seventh and the eighth edition the element itself is first discussed, then its binary compounds, followed by those of greater complexity (see Table 20). No compounds of an element are described before the element itself has been considered.[1] For example, only compounds of elements having "system numbers" less than 34 will be found in the section on mercury (see Table 19).

References are given in the body of the text and are intended to be complete to within six months of the publication date of any section (see back of each title page). A list of journals together with the abbreviations employed is given at the beginning of

[1] The date of publication is not a factor.

every section. Word abbreviations used in the text are also explained (see especially Sec. 1, pp. XVII–XX and XXXI–XXXII). The method used to indicate plurals is unique. There is no index; the "Inhalt" serves that purpose. In fact, except for the special features occasionally inserted, an index is unnecessary because of the standard arrangement.[1] A list of the elements discussed thus far will be found in Table 26.

MELLOR, J.W., "Comprehensive Treatise on Inorganic and Theoretical Chemistry," Longmans, Green & Co., New York, 1922– . This book "aims at giving a complete description of all the compounds known in inorganic chemistry, and where possible, these are discussed in the light of the so-called physical chemistry." Volume I gives a historical introduction and discusses hydrogen and oxygen (see Table 21). Volume II

TABLE 21.—CHAPTER HEADINGS IN VOL. I OF MELLOR'S "COMPREHENSIVE TREATISE"

Chapter	Contents
I	Evolution and Methodology of Chemistry
II	Combination by Weight
III	Hydrogen and the Composition of Water
IV	Physical Properties of Gases
V	Combination by Volume
VI	Classification of the Elements
VII	Hydrogen
VIII	Oxygen
IX	Water
X	Solutions
XI	Crystals and Crystallization
XII	Thermodynamics and Thermochemistry
XIII	Kinetic Theory of Atoms and Molecules
XIV	Ozone and Hydrogen Peroxide
XV	Electrolysis and the Ionic Hypothesis
XVI	Electrical Energy

takes up the halogens and alkalis including ammonia. Subsequent issues cover the other elements according to their grouping in the periodic table (see Table 22). Under any particular metal will be found the history of its discovery, methods of preparation, and physical and chemical properties.

[1] For brief discussions and criticisms of individual sections see the book reviews in various journals. Those in "Chemistry and Industry," Spring and Fall Publishers Numbers, are good.

There then follows a discussion of the hydrides, oxides, halides (F, Cl, Br, I), sulfides, sulfates, carbonates, nitrates, and phosphates. All other compounds of that particular element are described under the acid or acidic element involved. For example, lead chloride will be found under lead, but lead chromate is discussed under chromium. The double or complex salts considered in connection with any element include only those involving other elements previously discussed. Compounds such as carbides, silicides, and arsenides are described under carbon, silicon, arsenic, etc. Any intermetallic compounds are

TABLE 22.—SUMMARY OF MELLOR'S "COMPREHENSIVE TREATISE"

Volume	Date	Contents
I	1922	History, Introductory, H, O
II	1922	Halogens, Alkalis (including NH_4^+)
III	1923	Cu, Ag, Au, Ca, Sr, Ba, Radioactivity, Structure of Matter
IV	1923	Ra family, Be, Mg, Zn, Cd, Hg
V	1924	B, Al, Ga, In, Tl, Sc, Ce, Rare Earth Metals, C (Pt. 1)
VI	1925	C (Pt. 2), Si, Silicates
VII	1927	Ti, Zr, Hf, Th, Ge, Sn, Pb, Inert Gases
VIII	1928	N, P
IX	1929	As, Sb, Bi, V, Cb, Ta
X	1930	S, Se
XI	1931	Te, Cr, Mo, W
XII	1932	U, Mn, Ma, Re, Fe (Pt. I)
XIII	1934	Fe (Pt. II)
XIV	1935	Fe (Pt. III), Co
XV	1936	Ni, Au, Rh, Pd, Os, Ir
XVI	1937	Pt, General Index

considered in the same way as complex salts. In this particular, Mellor and Gmelin have the same system of arrangement—first a consideration of the new element, then a discussion of the compounds formed with those already described. The main difference is that, in Gmelin, compounds are arranged in order of the elements as previously discussed, whereas in Mellor the disposition is according to groups. It should also be noted that there is a subject index in each volume of Mellor. Even though this index is present, a desired compound can be located merely

by examining the backs of the various issues. Perhaps the only unsatisfactory feature about the whole compilation is the arrangement of references.

ABEGG, AUERBACH and KOPPEL, "Handbuch der anorganischen Chemie," S. Hirzel, Leipzig, 1905– . This critical survey was planned to occupy four volumes. Thus far Vol. II (two parts), Vol. III (three parts), and Vol. IV (four parts plus a fifth in progress) have been issued. With the exception of parts of Vol. IV, all divisions now available are reprints. Hence title-page dates should be ignored in favor of the "Geschlossen" date given at the end of each discussion along with the author's name. Considering the period covered, "Abegg" is probably

TABLE 23.—SUMMARY OF ABEGG'S "HANDBUCH"

Volume	Published	Reprinted	Contents
II, 1	1908	1922	1st Periodic Group. *Introduction to Atomic Wt. Detn.*, H, Li, Na, K, Colloid Chem. of Alkalis, Rb, Cs, Cu, Ag, Au
II, 2	1905	1922	2d Periodic Group. Be, Mg, Ca, Mortar, Sr, Ba, Ra, Zn, Cd, Hg
III, 1	1906	1922	3d Periodic Group. *Gen'l Notes on At. Wt.* II, B, Al, *Clay*, *Ultramarine*, Rare earths
III, 2	1909	1922	4th Periodic Group. C, Si, *Glass*, Ti, Ge, Zr, Sn, Pb, Th, Colloid chemistry
III, 3	1907	1922	5th Periodic Group. N, *NH_4 salts*, P, As, Sb, Bi, V, Nb, Ta (Nachträge)
IV, 1,1	1927	—	6th Periodic Group, 1st half. O_2, S, Se, Te, Po, RaF
1,2	1920	1921	6th Periodic Group, 2d half. Cr, Mo, W, U, Heteropolyacids
2	1913	1922	7th Periodic Group. F, Cl, Br, I, Mn
3,1	1928	—	8th Periodic Group. Noble gases
3,2	1930	—	8th Periodic Group. Iron
3,3	1934	—	8th Periodic Group. Cobalt
3,4	1937	—	8th Periodic Group. Nickel

the most valuable published analysis of inorganic literature. The various reviews were written by outstanding authorities in their fields. For example, Brauner prepared many of the sections concerned with atomic weights. Others, equally com-

petent, were responsible for a number of the important divisions. Many of the bibliographies are very useful, since they make it practically unnecessary to search the journal literature of the period covered. Incidentally some are chronologically, others topically, arranged. Several contain over a thousand references.

The arrangement of Abegg will be obvious from Table 23. As indicated in connection with books previously described, the special sections are well worth examination. An index in each volume makes the contents readily available.

FRIEND, J.N. (ed.), "Textbook of Inorganic Chemistry," Charles Griffin & Co., London, 11 vols., several in parts, 1914– . The scope of this series is not so ambitious as that of the books previously described, the object being to give "concise and suggestive accounts of the various topics." The arrange-

TABLE 24.—SUMMARY OF FRIEND'S "TEXTBOOK OF INORGANIC CHEMISTRY"

Volume	Date	Contents
I	1914	Introduction (Friend, Little & Turner), Inert Gases (Briscoe, 2d ed. reprinted 1919)
II	1924	Alkali Metals, Cu, Ag, Au (Walker)
III, 1	1925	Alkaline Earth Metals (Burr)
2	1926	Be, Mg, Zn, Cd, Hg (Gregory & Burr)
IV	1917	Al and Congeners, Rare Earths (Little, 2d ed. 1921)
V	1917	C, Si, Ti, Zr, Th, Ge, Sn, Pb (Caven, reprinted 1921)
VI, 1	1928	Nitrogen (Prideaux & Lambourne)
2	1934	Phosphorus (Prideaux)
3	1929	V, Nb, Ta (Marks)
4		As (Vallance) (In preparation)
5	1936	Sb, Bi (Thorneycroft)
VII, 1	1923	Oxygen (Friend & Twiss)
2	1931	S, Se, Te (Vallance, Twiss & Russell)
3	1926	Cr, Mo, W, U (Vallance & Eldridge)
VIII	1915	Halogens (Martin & Dancaster)
IX, 1	1919	Co, Ni, Pt family (Friend, 2d ed. 1923)
2	1921	Fe and its compounds (Friend)
X, 1	1928	Metal Ammines (Sutherland)
XI, 1	1928	Organometallic Compounds, Periodic Groups I–IV (Goddard & Goddard)
2	1930	Organometallic Compounds, Arsenic (Goddard)
3	1937	Organometallic Compounds, P, Sb, Bi (Goddard)
4	1937	Organometallic Compounds, Se, Te, Cr, Pt (Goddard)

ment is based upon the Periodic Table, one volume devoted to a discussion of the elements in each vertical column (see Table 24). Volume I, therefore, is concerned with the "Inert Gases"; Vol. II, with hydrogen, the alkali metals (including NH_4^+), copper, silver, and gold. Two extra volumes have been issued. One is devoted to the metal ammines, and the other to organo-metallic compounds. A special feature of Vol. I is the preliminary part entitled "An Introduction to Modern Inorganic Chemistry" comprising chapters on the fundamental laws of the science; the general properties of elements and compounds; methods for the determination of molecular, atomic, and equivalent weights; etc.

Certain additional details of organization should be noted. In all cases where the description of a double salt is desired it will be found under the element of highest division in the Periodic Table. Ferrous ammonium sulfate, for example, is listed under iron. The same applies to alloys. Brass is chiefly copper and zinc, so it is described under zinc in Vol. III. Chromium and manganese in chromates, dichromates, and permanganates form part of the acid radical. Such salts ought to be placed with the positive ion ($KMnO_4$ with potassium, etc.), but they are actually grouped under chromium in Vol. VII and manganese in Vol. VIII. The same sort of treatment is accorded molybdates, tungstates, etc. In general, cross references help to eliminate any confusion. Incidentally there is an author and subject index in each issue. Volume XI, Part II, has a patent index covering arsenic compounds. A synchronistic table of journals in the front of almost every issue is an aid in the examination of source references given as footnotes.

Pascal, P. (ed.), "Traité de chimie minérale," Masson et Cie., Paris, 12 vols., 1931–34. This series occupies an intermediate position between Mellor and Friend. It also resembles the former in mode of handling references[1] and the latter in treatment of several topics. The grouping of subject matter is indicated in Table 25. An important and commendable feature of the set is the promptness of completion. Unlike many other works

[1] References are grouped at the end of each important section as in Mellor, but, to insure their rapid location, at the foot of each text page there is a note indicating particular references applying to the statements on that page.

of a similar nature it was finished in about three years apparently without seriously affecting its quality. In fact, the principal criticism that the writer has encountered is a lack of exactness in the references. The references are not claimed to be exhaustive, but they should guide one to the more important sources. While there is an index in each volume it is too brief, hence of minor value.

TABLE 25.—SUMMARY OF PASCAL'S "TRAITÉ DE CHIMIE MINÉRALE"

Volume	Published	Contents
I	1931	Introduction, Air, Water, H, O, O_3, F, Cl, Br, I
II	1932	S, Se, Te, sulfuric acid industry
III	1932	N, P, As, nitrogen industry
IV	1933	Sb, Bi, V, Nb, Ta, B
V	1932	C, Si, Ti, Ge, Zr, Hf, NH_4
VI	1934	Alkali and alkaline earth metals, alkali salt industries
VII	1932	Be, Mg, Zn, Cd, Al, Ga, In, cement, glass
VIII	1933	Rare earths, Cu, Ag, Au, Hg
IX	1933	Sn, Pb, Tl, Mn, Re, Fe
X	1933	Ni, Co, Cr, complex salts
XI	1932	Mo, W, U, Th, Pt group
XII	1934	Radio elements, rare gases, alloys, *errors* in all 12 vols.

Some of the special sections in this series are: an excellent summary of the commercial production of sulfuric acid in Vol. II; the nitrogen industry in Vol. III; cements in Vol. VII; the rare earths in Vol. VIII including a brief account of their electronic structure, catalytic activity of their oxides, and the use of ceric sulfate as a volumetric reagent; and a general discussion of complex salts which occupies over 500 pages in Vol. X.

EVANS, U.R., "Metals and Metallic Compounds," Edward Arnold & Co., London, 4 vols., 1923. "This book is intended for the advanced student." The first volume contains a general discussion divided into two parts: "The Study of the Metallic State" (Metallography) and "The Study of the Ionic State" (Electrochemistry). Other volumes deal with the individual elements, in an order based upon the Periodic Table. Each section is divided into three parts: (*a*) pure chemistry of the metal and its compounds; (*b*) geology of the metal, i.e., probable

TABLE 26.—REFERENCE GUIDE TO INORGANIC CHEMISTRY TREATISES*

Element	Gmelin	Mellor	Friend	Abegg	Pascal
Al	35(34–)	V(24)	IV(21)	III,1(06)	VII(32)
Sb	18	IX(29)	VI(36) XI,3(36)	III,3(07)	IV(33)
As	17	IX(29)	VI( ) XI,2(3)	III,3(07)	III(32)
Ba	30(32)	III(23)	III,1(25)	II,2(05)	VI(34)
Be	26(30)	IV(23)	III,2(26)	II,2(05)	VII(32)
Bi	19(27)	IX(29)	VI(36) XI,3(36)	III,3(07)	IV(33)
B	13(26)	V(24)	IV(21)	III,1(06)	IV(33)
Br	7(31)	II(22)	VIII(15)	IV,2(13)	I(31)
Cd	33(25)	IV(23)	III,2(26)	II,2(13)	VII(32)
Ca	28	III(23)	III,1(25)	II,2(05)	VI(34)
C	14	V(24) VI(25)	V(21)	III,2(09)	V(32)
Cl	6(27)	II(22)	VIII(15)	IV,2(13)	I(31)
Cr	52	XI(31)	VII,3(26) XI,4(37)	IV,1,2(21)	X(33)
Co	58(30)	XIV(35)	IX,1(22)	IV,3,3(34)	X(33)
Cu	60	III(23)	II(24)	II,1(08)	VIII(33)
F	5(26)	II(22)	VIII(15)	IV,2(13)	I(31)
Ga	36(36)	V(24)	IV(21)	III,1(06)	VII(32)
Au	62	III(23)	II(24)	II,1(08)	VIII(33)
He	1(26)	VII(27)	I(14)	IV,3,1(28)	XII(34)
H	2(27)	I(22)	II(24)	II,1(08)	I(31)
I	8(31–3)	II(22)	VIII(15)	IV,2(13)	I(31)
Fe	59(20–)	XII(32) XIII(34) XIV(35)	IX,2(21)	IV,3,2(30–)	IX(33)
Pb	47	VII(27)	V(21)	III,2(09)	IX(33)
Li	20(27)	II(22)	II(24)	II,1(08)	VI(34)
Mg	27(37–)	IV(23)	III,2(26)	II,2(05)	VII(32)
Mn	56	XII(32)	VIII(15)	IV,2(13)	IX(33)
Hg	34	IV(23)	III,2(26)	II,2(05)	VIII(33)
Mo	53(35)	XI(31)	VII,3(26)	IV,1,2(21)	XI(32)
Ne	1(26)	VII(27)	I(14)	IV,3,1(28)	XII(34)
Ni	57	XV(36)	IX,1(22)	IV,3,4(37)	X(33)
N	4(34–6)	VIII(28)	VI,1(28)	III,3(07)	III(32)
O	3	I(22)	VII,1(24)	IV,1,1(27)	I(31)
Pd	65	XV(36)	IX,1(22)	—	XI(32)
P	16	VIII(28)	VI,2(34) XI,3(36)	III,3(07)	III(32)
Pt	68	—	IX,1(22) XI,4(37)	—	XI(32)
K	22(36–)	II(22)	II(24)	II,1(08)	VI(34)
Se	10	X(30)	VII,2(31) XI,4(37)	IV,1,1(27)	II(32)
Si	15	VI(25)	V(21)	III,2(09)	V(32)
Ag	61	III(23)	II(24)	II,1(08)	VIII(33)
Na	21(28)	II(22)	II(24)	II,1(08)	VI(34)
Sr	29(31)	III(23)	III,1(25)	II,2(05)	VI(34)
S	9	X(30)	VII,2(31)	IV,1,1(27)	II(32)
Te	11	XI(31)	VII,2(31) XI,4(37)	IV,1,1(27)	II(32)
Th	44	VII(27)	V(21)	III,2(09)	XI(32)
Sn	46	VII(27)	V(21)	III,2(09)	IX(33)
Ti	41	VII(27)	V(21)	III,2(09)	V(32)
W	54(33)	XI(31)	VII,3(26)	IV,1,2(21)	XI(32)
U	55(36)	XII(32)	II,1(25)	IV,1,2(21)	—
V	48	IX(29)	VI,3(29)	III,3(07)	IV(33)
Zn	32(24)	IV(23)	III,2(26)	II,2(05)	VII(32)
Zr	42	VII(27)	V(21)	III,2(09)	V(32)
NH_4 compds.	23(36–)	VII(28)	II(24)	III,3(22)	V(32)

* Adapted, with permission, from Mellon, *J.Chem.Education* **10**, 286 (1933). This table gives the volume, or section, and year of publication covering the discussion of each element for each treatise mentioned.

mode of formation of its important ores; (c) metallurgy (often the longest division). There is a subject and author index in each volume. Numerous references are given as footnotes.

Three reference books of inorganic chemistry, now chiefly of historical value, are Dammar's "Handbuch der anorganischen Chemie," Graham-Otto's "Lehrbuch der Chemie" (inorganic part by A. Michaelis), and Moissan's "Traité de chimie minérale."[1]

Advanced textbooks

No attempt will be made here to list any elementary books suitable for a beginning course in chemistry. A few outstanding texts useful in advanced inorganic courses and of particular value to students preparing for the doctorate are given in the following list which, of course, is not intended to be complete.

Caven and Lander, "Systematic Inorganic Chemistry," Blackie & Sons, London, 1930.

Ephraim, F., "Anorganische Chemie," T. Steinkopff, Dresden, 5th ed., 1934. There is an English translation by P.C.L. Thorne published by Gurney and Jackson, London. 2d ed. from 3d German ed. 1934.

Latimer and Hildebrand, "Reference Book of Inorganic Chemistry," The Macmillan Co., New York, 1929.

Lowry, T.M., "Inorganic Chemistry," The Macmillan Co., New York, 2d ed., 1932.

Morgan and Burstall, "Inorganic Chemistry," W. Heffer & Sons, Cambridge, England, 1937. A survey of modern developments.

Partington, J.R., "Textbook of Inorganic Chemistry for University Students," The Macmillan Co., New York, 4th ed., 1934.

[1] Dammar, O. (ed.), "Handbuch . . . ," F. Enke, Stuttgart, 4 vols., 1892–1903. A supplement was issued in 1905.

Graham-Otto (ed.), "Lehrbuch . . . ," F. Vieweg und Sohn, Braunschweig, 5th ed., 1878–89. 4 vols. inorganic plus 3 vols. organic.

Moissan, H. (ed.), "Traité . . . ," Masson et Cie., Paris, 5 vols., 1904–06.

REMY, H., "Lehrbuch der anorganischen Chemie," Akademische Verlagsgesellschaft, Leipzig, 2 vols., 1931.

ROSCOE and SCHORLEMMER, "Treatise on Chemistry," The Macmillan Co., New York. Vol. 1, Nonmetals, 5th ed., 1920. Vol. 2, Metals, 6th ed., 1923. Vol. 3, Organic. This has been a very popular reference book of the briefer type. The organic section has not been revised recently.

Laboratory manuals

Laboratory guides for inorganic chemistry are neither abundant nor up-to-date when compared with the literature available to organic technicians. To be sure, every elementary laboratory manual is replete with directions for making simple inorganic products; but for the advanced worker interested in fine points of technique and the preparation of more intricate compounds there is one outstanding reference book, viz., Stähler's "Handbuch der Arbeitsmethoden in der anorganischen Chemie,"[1] published in four volumes. This work first gives plans for the construction of a laboratory, then discusses its equipment, and finally considers a large number of inorganic processes. A rather brief summary is given in Table 27, but it may assist in emphasizing the fact that this compilation deserves to be used more widely. An outstanding feature of this book is the bibliography in Vol. IV, pp. 473–488, on the preparation of very pure compounds for atomic weight work. In the same volume there is also a subject index covering all six parts.

Another book dealing with high-grade materials is Archibald's "Preparation of Pure Inorganic Substances."[2] It is a compilation of methods advocated largely by atomic-weight investigators. The book opens with a chapter on purification processes, then discusses the various elements as they appear in the Periodic groups, i.e., Zero Group, Group I A, I B, etc. The rare earths are considered in Chap. VIII.

Other manuals on the subject of technique also contain helpful information. Among them are:

[1] Veit und Ges., Leipzig, Vols. I and III, 1913–14; Walter de Gruyter Co., Leipzig, Vols. II and IV, 1919–26. The major portion of Vol. IV was issued early in 1921; thus the date, 1926, is slightly misleading.

[2] John Wiley & Sons, New York, 1932.

TABLE 27.—SUMMARY OF STÄHLER'S "LABORATORY GUIDE"

Vol. I (1913) (787 pp.)

Construction and equipment of a laboratory
Mechanical operations, i.e., assembly of apparatus

Vol. II, Pt. 1 (1919) (654 pp.) General Physical Operations

Pressure determination	Crystallization
Liquefaction of gases	Drying
Temperature	Solution
Evaporation	Microscopy
Distillation and sublimation	Spectroscopy
Precipitation	Colorimetry

Pt. 2 (1925) (993 pp.) Special Physical and Chemical Operations

Microchemistry	High-pressure work
Membrane filters	NH_3 as a solvent
Electrometric analysis	SO_2 as a solvent
Radio-elements as indicators	Preparation of materials electrolytically
Crystal form	
Structure analysis and x-ray spectroscopy	Decomposition by silent electric discharge
High-vacuum technique	Decomposition by light
Spectrographic analysis	Methods of photochemistry

Subject and author indexes for Vol. II. Appendix

Vol. III, Pt. 1 (1913) (692 pp.) Physico-chemical Determinations

Weight	Surface tension	Viscosity
Volume	Thermal expansion	Diffusion
Density	Melting point	Heat conductivity
Osmotic pressure	Metallography	Calorimetry
Critical points	Boiling and sublimation points	Specific heat
Compressibility		Heat tone

Pt. 2 (1914) (862 pp.) Physico-chemical Determinations

Electrochemical determinations	Atomic weight
Magnetic measurements	Chemical kinetics and statics
Optical rotation	Graphical determinations
Refractive index	Chemical calculations
Radioactivity	Indexes for Vol. III

Vol. IV, Pt. 1 (1916) (326 pp.)

Preparation of gases
Preparation of colloidal material
Preparation of metals and alloys

Pt. 2 (1926) (246 pp.)

Thermite reactions
Phosphorescent materials
Mineral syntheses
Growing of crystals

List of very pure substances that have been prepared
Appendix. Author index for Vol. IV
General Subject Index for all 4 vols.

BILTZ and BILTZ, "Laboratory Methods of Inorganic Chemistry," John Wiley & Sons, New York, translated by Hall and Blanchard, 1928.

RIESENFELD, E.H., "Anorganisch-chemischer Praktikum, qualitative Analyse und anorganische Präparate," S. Hirzel, Leipzig, 11th ed., 1933. An English translation of the eleventh German edition has been prepared by P. Ray [see *J.Chem. Education* **11**, 62 (1934)].

VANINO, L., "Handbuch der präparativen Chemie," F. Enke, Stuttgart, 3d ed. of Vol. 1, inorganic part, 1925. (Vol. II deals with organic chemistry.)

ARENDT, R., "Technik der anorganischen Experimentalchemie," Leopold Voss, Leipzig, 4th ed. by L. Doermer, 1910. The first part (350 pp.) is concerned with apparatus and technique; the special section (about 600 pp.) deals with individual experiments. This book is of particular value to a demonstrator.

At the Chicago Convention of the American Chemical Society, in September 1933, a group of inorganic chemists advocated the publication of a series entitled "Inorganic Syntheses" to be similar in nature to the well-known "Organic Syntheses." The first volume will soon be available.

Hoffmann's Lexikon

Before concluding the discussion of inorganic sources Hoffmann's "Lexikon"[1] should be mentioned. "This dictionary . . . [is claimed] to be a complete catalog of the literature relating to inorganic chemistry; gives all analytic and synthetic compounds, all chemical individuals, and presents their full literature" down to Apr. 1, 1909.[2] The arrangement is described in the introductory part of Vol. I. Elements are listed in the order non-metals, light metals, heavy metals. A number is assigned to each element as shown in Table 28.

The elements are considered in numerical order, the element itself coming first, then combinations with those previously

[1] HOFFMANN, M.K., "Lexikon der anorganischen Verbindungen," J.A. Barth, Leipzig, 1910.

[2] The appendix has some data as recent as 1919.

TABLE 28.—CODE NUMBERS ASSIGNED TO ELEMENTS IN HOFFMANN'S "LEXIKON"

1. H	17. Li	34. Sb	50. Er	66. V
2. O	18. Rb	35. Bi	51. Yb	67. U
3. Cl	19. Cs	36. Ti	52. Sc	68. Ta
4. Br	20. Ca	37. Ge	53. Tu	69. Nb
5. I	21. Sr	38. Zr	54. Dy	70. Au
6. F	22. Ba	39. Sn	55. B	71. Pt
7. S	23. Ra	40. Th	56. Al	72. Ru
8. Se	24. Be	41. Ce	57. Ga	73. Rh
9. Te	25. Mg	42. La	58. In	74. Pd
10. N	26. Zn	43. Na	59. Mn	75. Ir
11. P	27. Cd	44. Pr	60. Fe	76. Os
12. C	28. Pb	45. Sm	61. Co	77. He
13. Si	29. Tl	46. Eu	62. Ni	78. Ne
14. NH_3	30. Cu	47. Gd	63. Cr	79. Ar
14*b*. NH_4	31. Ag	48. Y	64. Mo	80. Kr
15. K	32. Hg	49. Tb	65. W	81. X
16. Na	33. As			

described but in reverse sequence. If the following compounds are listed, the order would be:

F, 6	FIO, 6-5-2
FI, 6-5	FIH, 6-5-1
FIBr, 6-5-4	FBr, 6-4
FICl, 6-5-3	FBrCl, 6-4-3

Under each entry the data given are:

a. Ordinary formula.
b. Name of compound.
c. References to journal articles.
d. Reference to Gmelin, 7th ed.
e. Color, crystalline form or physical state.

There are two methods for using the book. (*a*) Obtain the number for each element in the formula of the desired compound, omitting water of crystallization; arrange the elements in descending numerical order and look for the highest number first, under that the next number, and so on. This is facilitated by the running title at the top of each page. (*b*) Use the alphabetical list of formulas in Vol. III. Its arrangement is based upon the following rule: In any compound the symbol occurring earliest in the alphabet is the one under which a compound is entered. For example, thorium bromide is entered under Br u. Th, and

beryllium carbonate is to be found under Be u. C. The Appendix in Vol. II contains a number of bibliographies[1] and references to other bibliographies. In Vol. III there is an interesting group of tables including abbreviations found in chemical literature, logarithms to five places, German expressions frequently employed, common names for minerals, etc.

SEARCHING THE LITERATURE

An examination of the literature for data regarding inorganic substances may be initiated in a variety of ways depending on just what information is wanted and how far back one desires to go. Obviously the more a searcher knows about his subject and his library the less time he will waste in examining irrelevant material and the more certain he will be that no important item has been overlooked when the investigation is concluded. As with any other art, skill is acquired only by practice, but the drill should be systematized. Consequently the following scheme is presented not with the expectation that it will be the most useful in all cases or that the order is the best possible for every study but as a tentative procedure to be modified by experience.

Perhaps the most important points are to decide just *what information is wanted* and what *subject headings* to look for. The problem may involve a single idea, be part of a larger subject to which it is more or less intimately related, or be divisible into more specific items. In any case it should be carefully examined, and all reasonable connections listed as search headings,[2] because two people are not likely to state an idea in the same terms without previous agreement. It is entirely reasonable, for example, to expect that the "oxidation of ferrous iron" might be thoroughly considered in some book under the subject "reduction of permanganate," "volumetric analysis," "iron, ions of," or some other topic without the entries "oxidation" or "ferrous iron" appearing in the index. Hence the suggestion to *analyze, generalize,* and *particularize* a subject before starting a search.

The next feature to consider is *where to look first.* Frequently the nature of the topic will suggest an answer to the question.

[1] Atomic weight determinations, inorganic colloids, metallic alloys, rare earths, etc.

[2] Subjects under which one might find desired data in an index.

If information published before 1909 is desired, Hoffmann's "Lexikon" might be examined. If book literature is wanted, possibly the card catalog or the Depository catalog would be serviceable. The use of both, however, requires knowledge of the author's name, the subject, or other details that may not be available initially. Of course, failure to find a book is not proof that none has been written or even that the material is not possessed by the library perhaps in a slightly different form.[1] Very often a search is started with only meager knowledge about the subject. In such cases a good encyclopedia might be of real service at the outset.

After the preparatory analysis has been completed, the sources given in the following outline should be of assistance in a thorough search.

- I. Preliminary survey
  - *A.* Encyclopedias (see above)
    - Fehling, Muspratt, Thorpe, Ullmann, etc.
      - (The bibliographies in Fehling deserve special mention)
  - *B.* Monographs
  - *C.* Textbooks
    - (Occasionally these give very good surveys of a field)
- II. Comprehensive treatises
  - Gmelin, Mellor, Friend, Abegg, Pascal, etc.
- III. Annual reviews
  - London Chemical Society
  - Society of Chemical Industry
  - Annual Survey of American Chemistry
  - Mineral Industry
  - "Fortschrittsberichte" in *Angew.Chem.*, etc.
- IV. Bibliographies of bibliographies
  - National Research Council Bull. 50, 71, 86
  - Sohon and Schaaf
- V. Abstract journals
  - *A.* Cumulative indexes
  - *B.* Annual indexes
  - *C.* Current issues
    - At least C. A. and Chem.Zentr. should be considered. There is some difference of opinion as to whether one should start with the most recent issue and work back or do the opposite.

[1] Recently Emich's "Microchemistry" was desired. Because the book was not available, the search was dropped in spite of the fact that Emich has published an extensive account of his work in Stähler's "Handbuch" which was on a near-by shelf at the time.

VI. Original articles
  A. Journal articles directly cited
  B. Patents directly cited
  C. Journals specializing in the subject
  D. Investigators specializing in the field

VII. Laboratory guides
  Stähler, Vanino, Arendt, etc.

VIII. General browsing
  Frequently as the end of a search is approached a casual inspection of books initially ignored may disclose some very valuable data.

When concluding any investigation whether in the laboratory or library it must be clearly understood that the work can never be completed. Regardless of how fruitful the study, there will always be many branches disclosed that upon further examination might yield even more valuable data. All the worker can do is to apply the law of diminishing returns to each part of his problem, decide where to stop, and then hope that his judgment was good.

ORGANIC CHEMISTRY

"Knowing that books exist is not enough. We must cultivate their acquaintance."

Guides to the literature of organic chemistry are better organized than those in any other division of the science. Over 300,000[1] carbon compounds are known, yet the published information about any one of them can be located in a few minutes. This situation is due largely to three factors. First, from the standpoint of an index, organic compounds may be arranged readily by employing a system based upon their empirical formulas and the number of carbon atoms per molecule. Second, for the purpose of discussion, organic compounds are conveniently grouped according to relationships revealed by their structural formulas. Lastly, the value of such aids has been so well established that every effort is made to keep them complete and up-to-date. Organic chemists owe an immeasurable debt to M.M. Richter and F.K. Beilstein for laying the foundations upon which such work is based. Owing to their activities, and subsequently to those of the German Chemical Society, today a *down-to-date* search of the literature for information concerning an organic compound involves simply an examination[2] of the formula indexes and Beilstein's "Handbuch" which summarize the more important data and refer directly to pertinent journal articles, monographs, etc. In outline the steps are as follows:

I. Formula Indexes[3]
   A. Richter, 3d ed. (Literature down to 1910)
   B. Stelzner, 5 vols. (Literature 1910–21)

[1] During the first decade of this century an average of seven thousand new compounds was reported each year, slightly less than twenty a day.

[2] Contrast with the procedure in an inorganic or physical chemistry search.

[3] These have been arranged by the compilers to form a complementary series. Of course other indexes may be used in so far as they cover the field, e.g., Chemical Abstracts, Annual Indexes from 1920 to date.

C. Chemisches Zentralblatt
1. Collective Indexes
VI 1922–24
VII 1925–29
VIII 1930–34
2. Annual Indexes
1935–

II. Beilstein
A. Fourth edition (literature to 1910)
B. First supplement (literature 1910–19)

III. Journal Articles, Monographs, etc.

Formula indexes

Richter's "Lexikon der Kohlenstoffverbindungen"[1] is a "systematic compilation of the carbon compounds arranged according to their empirical formulas." Under each formula are given the following data:

a. Name of each compound having the formula (isomers).
b. Ordinary state of the compound having the formula (isomers).
c. Physical constants (melting point, boiling point, etc.).
d. References to Beilstein, 3d ed., and the original literature (see below).

The "Introduction" to Richter's "Lexikon," in four languages, explains the arrangement. It depends, *first*, on the number of carbon atoms in the formula; *second*, on the number of other elements present; *third*, on which other elements are present; and, *fourth*, on the number of atoms of each other element. All formulas containing *one* C and *one* other element appear first, the order of consideration being:

H, O, N, Cl, Br, I, F, S, P, Ag . . . Zr.[2]

Assuming that the compounds indicated exist, the complete system can be illustrated as shown in Table 29.

[1] Leopold Voss, Leipzig, 3d ed., 1910–12. Cf. Gattermann-Wieland, "Laboratory Methods of Organic Chemistry," The Macmillan Co., New York, 1937. In this translation by W. McCartney will be found "Hints for Using the Literature of Organic Chemistry" which gives a brief discussion of Richter's "Lexicon."

[2] After phosphorus the other elements are considered in alphabetical order.

In order to facilitate the location of any formula, guide numbers have been placed in the upper, outer corner of each page. The first figure, in *arabic*, indicates the number of carbon atoms; the second figure, *roman*, shows how many other elements are present. For example the empirical formula of parachlor-

TABLE 29.—ARRANGEMENT OF ENTRIES IN RICHTER'S "LEXIKON"

1, I	CH_2O	CHO_2N	C_2O
CH	CH_2O_2	CHO_2N_2	C_2O_n
CH_2	.	.	.
CH_3	.	.	.
.	.	.	.
.	CH_nZr_n	CHO_nZr_n	C_2Zr_n
.	—	.	═
CH_n	CON	.	2, II
—	CON_2	$CH_2O_nN_n$	C_2HO
CO	CON_n	.	C_2HO_n
CO_2	.	.	.
CO_n	.	.	.
.	.	$CH_nO_nZr_n$	.
.	$COZr_n$	═	$C_2H_2O_n$
.	—	1, IV	.
—	CO_2N	CHONCl	.
CN_n	CO_2N_2	.	.
.	.	.	$C_2H_2Zr_n$
.	.	.	.
.	.	$CH_nO_nN_nCl_n$	.
CZr_n	CO_nN_n	.	.
═	.	.	$C_2H_nZr_n$
1, II	.	.	═
CHO	.	═	3, I
CHO_2	CO_nZr_n	2, I	C_3H_n
.	═	C_2H	.
.	1, III	C_2H_2	.
.	CHON	.	.
CHO_n	$CHON_2$	.	C_3Zr_n
.	.	.	.
.	.	C_2H_n	.
.	.	—	.
$CHZr_n$	$CHOZr_n$		═
—	—		$C_nH_nO_n$ . . .

benzoic acid is $C_7H_5O_2Cl$, the elements being arranged in the order specified to promote the search. This compound may be found by first securing the volume containing C-7 entries, then locating the guide figure 7 followed by III; finally, by glancing

down the pages thus marked, the desired compound is quickly discovered. This should be done, of course, in both the main volume and the corresponding supplement. While there is an index in Vol. IV that may be helpful at times, especially when the formula for a desired compound is unknown, the method just described is usually more expeditious.

Richter's "Lexikon" contains references to the literature describing methods of preparation and properties but not to purely theoretical papers. It is a collective index to the third edition of Beilstein[1] and to the Chemisches Zentralblatt[2] from 1902 to 1910.

Stelzner's "Literatur-Register" is a continuation of Richter's "Lexikon," starting with the year 1910 and ending with 1921. The five volumes are arranged as shown in Table 30.

TABLE 30.—ARRANGEMENT OF STELZNER'S "LITERATUR-REGISTER"

Volume	Period Covered
I	1910 and 1911, plus Index
II	1912 and 1913, plus Index
III	1914 and 1915, plus Index
IV	1916–17–18, plus Index
V	1919–20–21, plus Index

Under each formula the author planned to give references to the original literature and the Zentralblatt abstracts covering:

a. Constitution and configuration.

b. Occurrence (isolation and detection). Preparation (purification).

c. Physical properties and reactions.

d. Chemical properties.

e. Physiological properties.

[1] Beilstein references are given as follows: "CO, Kohlenoxyd . . . I, 543," which indicates Vol. I, p. 543. If an asterisk is placed before the roman numeral the reference is to the supplement rather than the main volume.

[2] Zentralblatt references are given after the original journal citation thus:

"*C. r.* **133**, 938   *C.* **1902** [1] 207"

which indicates that the original article appeared in the *Compt. rend.*, Vol. 133, p. 938, and an abstract is in the 1902 volume of the Zentralblatt, Part I, p. 207. This is an important help to one who reads German but not the language of the original article.

f. Determination.
g. Uses.
h. Salts, esters, and other compounds.[1]

The Zentralblatt indexes give references only to abstracts appearing in that journal. The cumulated indexes materially expedite a search through this source. There is, however, no subject index to the current issues other than the table of contents on the cover page. The author list is obviously of little value unless one is familiar with the names of those working in the field under consideration.

BEILSTEIN'S "HANDBUCH"[2]

Friedrich Konrad[3] Beilstein was born, of German parents, in St. Petersburg, Russia, in 1838. Following his elementary training he studied under Bunsen and Wöhler and became Privatdozent at Göttingen in 1860. Six years later he joined the staff of the Technical Institute at his native city and remained there until his death in 1906. Early in academic life he had

TABLE 31.—SUMMARY OF EDITIONS OF BEILSTEIN'S "HANDBOOK"

Edition	Published	Volumes	Pages
1st	1880–2	2	2,201
2d	1885–9	3	4,080
3d	1892–9	4	6,844
3d (suppl.)*	1896–1906	5	4,604
4th	1919–	27(?)	
4th (suppl.)	1928–		

* Beilstein died two weeks after the last volume of this supplement had been issued.

begun the assembly of all available information on organic chemistry for his own use. Subsequently he decided to publish the results of this work in a handbook. The first "Lieferungen" (installments), written in German, appeared in 1880. Other

[1] Cf. Vol. I, pp. XVI–XL.

[2] The introductory discussion is based on an article by Jacobson, *Naturwissenschaften*, **7**, 222–5(1919), and the preface to Vol. I, p. XI–XVII.

[3] For a biography of Beilstein see Hjelt, *Ber.*, **40**, 5041–78 (1907). It is interesting that German references to Beilstein use Friedrich Konrad as his given names, whereas the necrological notice in *Niva* (Issue No. 44, p. 706, 1906) uses Theodore Theodorovitch.

parts soon followed, the task being finished 2 years later. The second and third editions required about 15 years' labor. They were compiled without assistance except for that of Paul Jacobson who prepared the supplement to the third edition with the aid of the German Chemical Society. This supplement included data down to 1902.

After its completion plans were considered for extension of the work. A second supplement was obviously impracticable, the old system of arrangement having become inadequate. Consequently Jacobson and Prager undertook the development of a new system. With the help of Paul Schmidt and Dora Stern details were settled in 1907. The next five years were devoted to arrangement of data in the third edition according to the new scheme. Information published between 1903 and 1910 was arranged during the years 1913–16. World War distractions delayed publication of Vol. I until early in 1919. Other volumes have appeared at short intervals since then; 26 are now available, together with 25 volumes of the first supplement (started in 1928).

The last edition of Beilstein's "Handbook" differs from its predecessors in size and scope of information as well as in arrangement. Without regard to the difference in number of substances considered, the space devoted to a few compounds will illustrate the first point.

Compound	Pages	
	3d ed.	4th ed.
C_2H_5OH	7	22
C_2H_2	2	16
CH_2O	1.5	16
Acetates	24	60

Scope

The new edition of Beilstein is intended to be a complete summary of all published data on organic compounds down to Jan. 1, 1910, i.e., coextensive with the third edition of Richter's "Lexikon." In addition, the first supplement covers the

TABLE 32.—KEY TO BEILSTEIN'S "HANDBUCH DER ORGANISCHEN CHEMIE"*

Acyclic Compounds	Vol. I–IV
Isocyclic Compounds	Vol. V–XVI
Heterocyclic Compounds	Vol. XVII
Naturally Occurring Compounds	Vol. (in preparation)

ACYCLIC COMPOUNDS

Vol. Contents

I. Hydrocarbons
  Methane, 56;† Ethane, 80; Ethylene, 180
 Hydroxy compounds
  Methyl alcohol, 273
  Ethyl alcohol, 292
   Ethyl ether, 314
  Glycerol, 502
 Carbonyl compounds
  Formaldehyde, 558; Acetone, 635
 Hydroxy-carbonyl compounds
  Aldol, 824; Pentoses, 858; Hexoses, 878.

II. Carboxylic Acids
  Formic Acid, 8; Acetic Acid, 96; Oxalic Acid, 502

III. Carboxylic Acids
  Hydroxy
   Carbonic Acid, 3; Glycolic Acid, 228; Lactic Acid, 261; Citric Acid, 556
  Carbonyl
   Glyoxalic Acid, 594; Acetoacetic Acid, 630
  Hydroxy-carbonyl
   Glycuronic Acid, 883

IV. Sulfonic Acids
  Hydroxy, 13
  Carbonyl, 21
 Amines
   Methylamine, 32
  Hydroxy amines
   Amino-ethyl alcohol, 274
  Carbonyl amines
   Aminoacetaldehyde, 307; Aminoacetone, 314
  Hydroxy-carbonyl
  Amino acids
   Glycine, 333
 Hydroxylamines, 534
 Hydrazines, 546

* This table indicates the scope of each volume and gives page references to many index and key compounds by means of which derivatives can be located by anyone familiar with the system of arrangement.

† This figure is the page number in the volume specified.

TABLE 32.—KEY TO BEILSTEIN'S "HANDBUCH DER ORGANISCHEN CHEMIE."—(*Continued*)

Azo compounds (R·N:NH), 562

Metallic Compounds, 580. The order is

P	Ge	Tl	Cd
As	Sn	Be	Hg
Sb	Pb	Mg	Na
Bi	B	Ca	Au
Si	Al	Zn	Pt

ISOCYCLIC COMPOUNDS

Ring structures with only carbon in the ring

Vol. Content

V. Hydrocarbons
- Cyclopropane, 15
- Benzene, 179, Toluene, 280, Xylene, 362
- Naphthalene, 531, Diphenyl, 576; Anthracene, 657
- Triphenylmethane, 698

VI. Hydroxy Compounds
- Alcohols, phenols, phenol-alcohols
  - Menthol, 28; Phenol, 110
  - Cresol, 349; Naphthol, 596
  - Resorcinol, 796; Pyrogallol, 1071

VII. Carbonyl Compounds
- Aldehydes, ketones, ketenes, quinones
  - Camphor, 101; Benzaldehyde, 174
  - Acetophonone, 271; Benzophenone, 410
  - Benzoquinone, 600; Benzil, 747

VIII. Hydroxy-carbonyl Compounds
- Salicylic aldehyde, 31; Benzoin, 166
- Aurine, 361; Alizarin, 439

IX. Carboxylic Acids
- Benzoic, 92; Cinnamic, 572; Phthalic, 791

X. Hydroxy-carboxylic Acids
- Salicylic, 43
- Carbonyl carboxylic acids, 594
- Hydroxy-carbonyl carboxylic acids, 943

XI. Acids
- Sulfinic, 2
- Sulfonic, 23
  - Benzene sulfonic, 26; Naphthalene sulfonic, 155
- Hydroxy sulfonic
  - Phenol sulfonic, 234; Naphthol sulfonic, 269
- Carbonyl sulfonic, 314

TABLE 32.—KEY TO BEILSTEIN'S "HANDBUCH DER ORGANISCHEN CHEMIE."
—(*Continued*)

Vol. Contents

Hydroxy-carbonyl sulfonic, 345
Carboxylic sulfonic, 368
Se and Te Acids, 422

XII. Amines (Mono- only)
Anilin, 59; Toluidine, 772
Benzylamine, 1013; Naphthylamine, 1212

XIII. Polyamines
Diamines
o-Phenylenediamine, 6; Benzidine, 214
Triamines, 294
Hydroxy amines, 348
o-Aminophenol, 354; Pararosanilin, 750

XIV. Carbonyl Amines
Amino-benzaldehyde, 21; Amino-acetophenone, 41
Amino-benzophenone, 76; Amino-anthraquinones, 177
Hydroxy-carbonyl amines, 233
Amino carboxylic acids, 299
Anthranilic acid (amino-benzoic acid), 310
Amino hydroxy-carboxylic acids, 577
Amino sulfonic acids,
Benzene compounds, 681; toluene compounds, 719

XV. Hydroxylamines
Hydrazines
Phenylhydrazine, 67

XVI. Azo Compounds
Azobenzene, 8; derivatives of o-cresol, 130; derivatives of benzoic acid, 225
Diazo compounds
Diazobenzene, 428
Azoxy compounds, 620
Nitramines and nitrosohydroxylamines, 661
Phosphorus compounds
Phenylphosphine, 757
Arsenic compounds
Phenylarsine, 826
Antimony compounds, 891
Bi, Si, Sn, Pb, B, Tl, Mg, Ca, Hg, Na, Pt

HETEROCYCLIC COMPOUNDS

Ring structures with other elements besides carbon in the ring

TABLE 32.—KEY TO BEILSTENI'S "HANDBUCH DER ORGANISCHEN CHEMIE."
—(*Continued*)

Vol. Contents
XVII. One Cyclic Oxygen (S, Se, or Te)
  Stem nuclei
    Furfurane, 27
  Hydroxy compounds, 104
    Furfuralcohol, 112
  Carbonyl compounds, 234
    Furfural, 272
XVIII. One Cyclic Oxygen (continued)
  Carbonyl compounds (continued), 1
  Carboxylic acids, 261
    Pyromucic acid, 272
  Sulfonic acids, 567
  Amines, 583; Hydroxylamines, 637; Hydrazines, 639
  Azo compounds, 643; Diazo compounds, 651
  Carbon-metal compounds, 653
XIX. Two Cyclic Oxygens
  Stem nuclei
    Ethylene dioxide, 1; dixanthyl, 61
  Hydroxy compounds, 63
  Carbonyl compounds
  Ethylene carbonate, 100
    Fluorescein, 222
      Eosin, 228
  Carboxylic acids, 267
  Amines, 328
 Three cyclic oxygens, 381
 Four cyclic oxygens, 433
 Five cyclic oxygens, 459 . . .
XX. One Cyclic Nitrogen
  Piperidine, 6; pyrrol, 159; pyridine, 181; indol, 304; quinoline, 339; carbazol, 433
XXI. One Cyclic Nitrogen (continued)
  Hydroxy compounds
    Hydroxypyridine, 43; indoxyl, 69; hydroxyquinoline, 77
  Carbonyl compounds, 236
    Succinimide, 369; isatin, 432; phthalimide, 458
XXII. One Cyclic Nitrogen (concluded)
  Carboxylic acids
    Quinoline carboxylic acid, 74
  Hydroxy-carboxylic acids, 190
  Carbonyl-carboxylic acids, 284
  Sulfonic acids, 386

TABLE 32.—KEY TO BEILSTEIN'S "HANDBUCH DER ORGANISCHEN CHEMIE."
—(*Continued*)

Vol.	Contents
	Quinoline sulfonic acid, 390
	Amines, 419
	Amino carboxylic acids, 541
	Azo compounds, 572
XXIII.	Two Cyclic Nitrogens
	Stem nuclei
	Diazomethane, 25; pyrimidine, 89; dipyridyl, 199
	Hydroxy compounds, 348
	Cinchonine, 424; indigo white, 538
XXIV.	Two Cyclic Nitrogens (continued)
	Carbonyl compounds
	Hydantoin, 242; uracil, 312; indigo, 416; alloxan, 500
XXV.	Two Cyclic Nitrogens (concluded)
	Hydroxy-carbonyl compounds
	Hydroxy-indanthrene, 102
	Carboxylic acids, 108
	Sulfonic acids, 286
	Amines, 308
	Azo compounds, 535
XXVI.	Three Cyclic Nitrogens to Eight Cyclic Nitrogens

SUPPLEMENTS

Supplemental Vols. I to XXV of the first series have been issued. They correspond in arrangement to the main volumes. Any detailed inventory of their content is, therefore, unnecessary.

literature from 1910 to 1919, while the second supplement (in preparation) deals with publications of the next decade. Where available each entry includes the information listed below, together with references to the important original articles.

Name, formula, structure, and configuration
Bibliography, if in book form
Important historical notes
Occurrence, formation, preparation
Properties
  Color, crystallography, physical constants. . . .
Chemical changes
  Action of heat, light, electricity, inorganic reagents, organic reagents
Physiological properties
Uses (technical)

Analysis
Detection, determination of structure, quantitative analysis
Addition compounds and salts
Conversion products of unknown structure

Aids

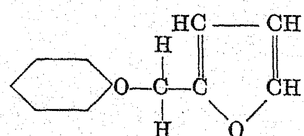
Four aids are available to anyone wishing to consult the Handbook. There is (*a*) a detailed table of contents and (*b*) an index in each volume, (*c*) a code system locating each substance by means of an index or key compound and a number, and (*d*) a definite scheme of arrangement. Since the first three are closely related to and dependent upon the last, the "Beilstein system" will be discussed first.[1]

Depending upon their structure, or source, all organic compounds fall into four main divisions which are considered in the order:

a. *Acyclic* or chain compounds.
b. *Isocyclic* or ring compounds, the ring consisting solely of carbon atoms.
c. *Heterocyclic* ring compounds, the ring containing other elements in addition to carbon.
d. *Naturally occurring compounds* the structure of which is incompletely known.

Principle of latest position

Any compound is converted into its "stem nuclei," or basic groups, by substituting hydrogen for all other elements attached to carbon without disturbing rings. For example, the nuclei of



[1] Cf. Beilstein, 4th ed., Vol. I, pp. 1–46.

Prager, *et al.*, "System der organischen Verbindungen," Julius Springer, Berlin, 1929. "A Guide to the Use of Beilstein's Handbuch der organischen Chemie."

Huntress, E.H., "A Brief Introduction to the Use of Beilstein's Handbuch der organischen Chemie," John Wiley & Sons, New York, 1938.

Richter, F., "Short Introduction to the Arrangement of Beilstein's Handbook . . . ," Julius Springer, Berlin, 1936.

are benzene, methane, and furane. Whenever a substance, thus converted, yields nuclei belonging to more than one division the compound will be found in the last division to which any one of its nuclei belongs. This is in accord with the "principle of latest position" which is one of the most important general rules governing the arrangement. It may be stated as follows:

In all cases where a compound can be considered as derived from two or more parent compounds, or contains two or more different functioning groups, it will be found under the last one discussed according to the basic classification.

Other basic rules

Another general principle is that compounds are arranged in order of decreasing saturation and increasing complexity (see p. 138). In the heterocyclic division, substances having rings containing oxygen[1] in addition to carbon are considered first; then the corresponding nitrogen compounds are discussed. The fourth division is arranged as shown in Table 33. Further

TABLE 33.—ARRANGEMENT OF DIVISION IV IN BEILSTEIN'S "HANDBUCH"*

Hydrocarbons (Petroleum, carotin . . .)
Ethereal oils
Sterols (Ergosterol, cholesterol . . .)
Fatty oils and fats
Waxes
Resins, balsams, saps (amber, turpentine, rubber, storax . . .)
Carbohydrates (Polysaccharides as lactose, maltose, starches, cellulose . . .)
Glucosides (Coniferin, saponin, amygdalin . . .)
Coupled glycuronic acids
Alkaloids (Morphine, strychnine, ptomaine . . .)
Phosphatides (Lecithin)
Proteins (Albumin, peptone, hemoglobin . . .)
Enzymes
Nitrogen-free materials not belonging to earlier groups (Asphalt . . .)
Nitrogenous substances not previously considered (Chlorophyll, litmus . . .)
Natural products not belonging to any previous group (Humin, graphitic acid, cork, lignin . . .)

* From Vol. I, pp. XXXIV–XXXV.

information regarding this section is not available, but the others can be discussed in greater detail.

[1] Or its equivalents: S, Se, or Te.

Functional, substitution, and replacement groups

When a stem nucleus is altered by replacing hydrogen with another element or a combination of elements the substituent may be modifiable, or it may not. If it is, (*a*) oxygen may function as the connecting link, or (*b*) sulfur, selenium, or tellurium may act in the same capacity. Products in which the substituent is not alterable form a third group. Should X, in the compound CH_3X, represent OH, the H can be removed and some other element or combination given its position, the oxygen acting as a connecting link. When the O is replaced with S an example of the second group is obtained. If X indicates Cl or NO_3,[1] further change at that position is impossible without complete removal of the original substituent. All groups capable of modification, excepting CH_3, C_2H_5, etc.,[2] are called "functional"; all in which S, Se, or Te has been substituted for a functional oxygen are named "replacement groups," while all incapable of alteration are termed "non-functional" or "substitution groups" (see Table 35 for functional and p. 139 for the non-functional groups). Whenever both functional and non-functional groups are attached to the same carbon, special rules are applied which will be discussed later. These rules eliminate, for the purposes of classification, cases involving mixtures such as functional plus non-functional groups attached to the same carbon. Consequently there are only three types as stated.

Classes

Returning to the main divisions the heterocyclic is unlike the acyclic and isocyclic in that it is first separated into hetero-classes (see Table 34). The acyclic division, the isocyclic division, and all hetero-classes are divided into 28 *main classes* the first

[1] Whether NO_3^- can be changed to NO_2^- in the laboratory is not a factor. The compilers have decided to regard them as independent groups for the purpose of arranging entries in the handbook. Other peculiarities of a similar nature may confuse a beginner. He will soon realize, however, that they are necessary to specifically locate compounds by eliminating alternatives.

[2] These are eliminated because they raise a stem nucleus, or side chain, one or more steps in the homologous series.

TABLE 34.—HETERO-CLASSES IN THE HETEROCYCLIC DIVISION

Compounds containing *one* cyclically bound oxygen (or S, Se, Te)
Compounds containing *two* cyclically bound oxygen (or S, Se, Te)
Compounds containing *three* cyclically bound oxygen (or S, Se, Te), etc.

Compounds containing *one* cyclically bound nitrogen
Compounds containing *two* cyclically bound nitrogen
Compounds containing *three* cyclically bound nitrogen, etc.

Compounds containing *one* cyclic nitrogen and *one* cyclic oxygen . . .
Compounds containing *one* cyclic nitrogen and *two* cyclic oxygen . . .
Compounds containing *one* cyclic nitrogen and *three* cyclic oxygen, etc.

Compounds containing *two* cyclic nitrogens and *one* cyclic oxygen . . .
Compounds containing *two* cyclic nitrogens and *two* cyclic oxygen . . .
Compounds containing *two* cyclic nitrogens and *three* cyclic oxygen, etc.

of which consists of the stem nuclei, i.e., hydrocarbons in the acyclic and isocyclic divisions, while the others depend upon the functional group present (see Table 35).

TABLE 35.—MAIN CLASSES AND FUNCTIONING GROUPS OF THE ACYCLIC AND ISOCYCLIC DIVISIONS AND HETERO-CLASSES*

	Class	Characterizing Groups
1.	Stem nuclei	
2.	Hydroxy compounds	—OH
3.	Carbonyl compounds	—CHO or =C=O
4.	Carboxylic acids	—COOH
5.	Sulfinic acids	$—SO_2H$
6.	Sulfonic acids	$—SO_3H$
7.	Selenous and selenic acids	$—SeO_2H$, $—SeO_3H$
8.	Amines	$—NH_2$
9.	Hydroxylamines	—NHOH
10.	Hydrazines	$—NH{\cdot}NH_2$
11.	Azo compounds	—N:NH
12–22.	Other N derivatives	
23–28.	Compounds in which C is united directly to a metallic element. The order is according to Periodic Groups 5, 4, 3, 2, 1, 6, 7, 8; e.g., Class 23 consists of compounds in which C is bound to P, As, Sb, or Bi.	

* For a complete list see Beilstein, Vol. I, p. 9–10.

Subclasses

Within each main class there are subclasses. In Class 1, for example, these are the so-called homologous series. They are arranged in order of decreasing saturation thus:

Acyclic division	Isocyclic division	Heterocyclic division
C_nH_{2n+2}	C_nH_{2n}	$C_nH_{2n+1}N$
C_nH_{2n}	C_nH_{2n-2}	$C_nH_{2n-1}N$
C_nH_{2n-2}	C_nH_{2n-4}	$C_nH_{2n-3}N$

Each subclass is composed of rubrics, usually called "individual members of a series"; e.g., within the methane series are methane and its derivatives, ethane and its derivatives, etc. The arrangement would appear in outline as follows:

Main division........................ Acyclic
  Main class........................... Hydrocarbon
    Subclass............................. Methane series
      Rubric............................. Methane

In Class 2, hydroxy compounds, the subclasses are arranged in order of increasing number of hydroxyl radicals. The same is true of later classes except that additional subclasses arise through the presence of more than one sort of functional group in the same compound. Starting with Class 5 this would lead to complications except for the introduction of sub-subclasses. The situation is, perhaps, best revealed by the following examples:[1]

A. Acyclic division
  Main Class 4, Carboxylic acids
    Subclass A. Monocarboxylic acids (Formic acid . . .)
      B. Dicarboxylic acids (Oxalic acid . . .)
      C. Tricarboxylic acids, etc. (Methanetricarboxylic acid . . .)
        . . .
      L. Hydroxy-carboxylic acids
        1. With 3 oxygens (carbonic acid . . .)
        2. With 4 oxygens, etc.
        . . .
      M. Carbonyl-carboxylic acids (glyoxylic acid . . .)
        1. With 3 oxygens, etc.
        . . .
      N. Hydroxy-carbonyl carboxylic acids
        1. With 4 oxygens, etc.

[1] Compiled from the "Table of Contents" of Vols. II, III, and IV.

B. Acyclic division

Main Class 8, Amines

Subclass A. Mono-amines (Methylamine . . .)

B. Diamines (Methylene diamine), etc.

. . .

D. Hydroxy amines

1. Amino derivatives of monohydroxy compounds
2. Amino derivatives of dihydroxy compounds, etc.

. . .

E. Carbonyl amines

Amino derivatives of monocarbonyl compounds

. . .

F. Hydroxy-carbonyl amines

1. Amino derivatives of the 2 O compounds
2. Amino derivatives of the 5 O compounds

. . .

G. Amino-carboxylic acids (Amino acids)

1. Amino derivatives of monocarboxylic acids (Glycine . . .)
2. Amino derivatives of dicarboxylic acids (Amino-malonic acid . . .) etc.

. . .

H. Amino-hydroxy carboxylic acids

1. Amino derivatives of the 3 O compounds, etc.

. . .

I. Amino-carbonyl carboxylic acids

. . .

K. Amino-sulfonic acids

1. Amino derivatives of monosulfonic acids

L. Amino-carboxylic sulfonic acids

Coupling or anhydrosynthesis

The derivatives of Class 1 compounds (Table 35) are all non-functional because the introduction of a functional group immediately transfers the substance to another class. The order of arrangement of non-functional or substitution derivatives is

$$—F, —Cl, —Br, —I, —NO, —NO_2, —N_3$$

Beginning with Class 2 all three types of derivatives are possible. Functional derivatives are considered first, then substitution, and finally replacement. Derivatives of functional compounds are of two sorts, those theoretically obtainable by coupling the parent, or index, compound with (*a*) an organic

molecule and (*b*) an inorganic molecule. The coupling process is termed *anhydro-synthesis* because water is eliminated in the

TABLE 36.—INORGANIC COUPLING COMPOUNDS IN ORDER OF CONSIDERATION

I. Hydrogen peroxide $HO \cdot OH$

II. Oxygen acids

A. Halogen acids

$HO \cdot Cl$	$HO \cdot ClO$	$HO \cdot ClO_2$	$HO \cdot ClO_3$
$HO \cdot Br$		$HO \cdot BrO_2$	
$HO \cdot I$		$HO \cdot IO_2$	$HO \cdot IO_3$

B. Sulphur acids

Sulfoxylic	$HO \cdot S \cdot OH$
Hyposulfurous	$HO \cdot (SO)_2 \cdot OH$
Sulfurous	$HO \cdot SO \cdot OH$
Sulfuric	$HO \cdot SO_2 \cdot OH$

(Selenium and Tellurium acids in same order)

C. Nitrogen acids

Hyponitrous	$HO \cdot N{:}N \cdot OH$
Nitrous	$HO \cdot NO$
Nitric	$HO \cdot NO_2$

D. Phosphorus acids

Phosphorous	$HO \cdot P(OH)_2$
Phosphoric	$HO \cdot P(OH)_3$, etc.

(Arsenic acids in the same order)

E. Silicon acids

Silicic	$HO \cdot SiO \cdot OH$, etc.

III. Halide acids

HF, HCl, HBr, HI

IV. Nitrogen compounds, coupling being effected through use of H directly attached to N

$$NH_3,\ H_2N \cdot OH,\ HNO\left(HN\langle{}^{OH}_{OH} \text{ and } H_2N\langle{}^{O}_{OH}\right),\ HNO_2$$

Hydrazine, NH_2NH_2, and other 2N compounds

Compounds containing 3N($NH_2 \cdot NH \cdot NH_2$), HN_3, etc.

Compounds containing more than 3N

V. Compounds of P, As, Sb, Bi, and other elements of the periodic groups (4, 3, 2, 1, 6, 7, 8) in which H is attached directly to the element, in so far as they have not been previously considered

operation. The following restrictions apply:

a. An organic coupling compound must contain a C—OH group.

b. No organic compound may be used as a coupling compound before it has been described in the text.

c. Inorganic coupling compounds must contain a replaceable hydrogen atom (see Table 36).

Examples:

Index compound	Coupling compound	Derivative
$C_2H_5O \mid H$	$HO \mid CH_3$	$C_2H_5OCH_3$
$C_2H_5 \mid OH$	$H \mid OSO_2OH$	$C_2H_5OSO_3H$
$CH_3C(=O) \mid OH$	$H \mid NH_2$	$CH_3C(=O)—NH_2$

It should be noted that the following are not considered as legitimate couplings, the first because it gives an index compound of another class and the second because it gives a non-functional derivative previously considered:

$$C_2H_5OH + NH_3 \rightarrow C_2H_5NH_2 + H_2O$$
$$C_2H_5OH + HCl \rightarrow C_2H_5Cl + H_2O$$

Degrees of derivatives

Derivatives may differ in degree. The examples given above are of the first degree. They result from the anhydro-synthesis of an index and a coupling compound. Second- and third-degree derivatives are obtained by alteration of the coupled part.

First degree	Second degree	Third degree
$C_2H_5OCH_3$	$C_2H_5OCH_2Cl$	
	$C_2H_5OCHCl_2$	
	$C_2H_5OCCl_3$	
$C_2H_5ONH_2$	$C_2H_5ONHCH_3$	$C_2H_5ONHCH_2Cl$
	$C_2H_5ONCl_2$	$C_2H_5ONHCHCl_2$, etc.

Precedence

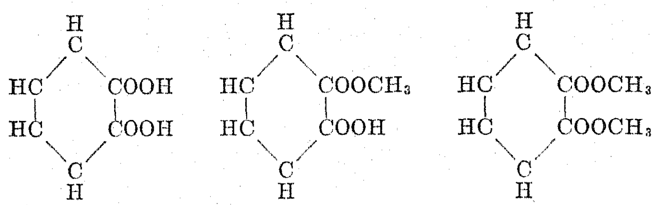
The rules of order are:

a. Derivatives involving organic coupling compounds are taken up in the order of arrangement of the coupling compounds in the text.

b. A derivative containing a new group is first combined with all preceding groups before multiplication of the new group.

c. All known alterations of the first degree are discussed before any of the second degree, all of the second before any of the third, etc.

When an index compound has more than one functioning group two modes of arrangement are used. If all groups are alike the coupling compound will be united first with one, then two, and so on, e.g.:



If the functioning groups are different all of the derivatives of one are considered then those of another, e.g., in $C_6H_4NH_2$-COOH all of the alterations involving the COOH appear first, then those of the NH_2. Of course in cases of mixed functional groups the principle of latest position applies as regards placement of the index compound.

Compounds having tautomeric or desmotropic forms are discussed in detail under one modification which is designated the "index compound." The other form will be found in its proper place but will have only a cross reference to the first one. Consequently the rules for selection of the index form will not be given here. They may be found in Beilstein, Vol. I, p. 34, paragraphs 37–46.

Because of the elementary nature of this discussion other details also have been omitted such as the disposition made of diphenyl and triphenyl methane dyes and dyes containing heterocyclic stem nuclei. A good explanation will be found in sections 47–8 of Beilstein, Vol. 1, pp. 43–6.

Summary of arrangement

In concluding the discussion of arrangement a brief outline showing the major steps may help to summarize what has been said. For the sake of emphasis details have been omitted.

Main division
  Main class
    1. Hydrocarbons (Order: increasing complexity, decreasing saturation)
      Index compound
        Substitution derivatives
          Order: $-F$, $-Cl$, $-Br$ $-I$, $-NO$, $-NO_2$, $-N_3$
    2. Hydroxy compounds
      One hydroxyl group
        Index compound
          Addition compounds, salts . . .
          Functional derivatives
            With organic coupling compounds
              Order same as that of the coupling compounds in the text
            With inorganic coupling compounds
              Order indicated in Table 36
          Substitution derivatives
            Order same as above
          Replacement derivatives
            Order same as that of the corresponding oxygen compounds
      Two hydroxyl groups

. . . .

    3. Carbonyl compounds
      One carbonyl group, etc.

Use

A place for every compound having been provided, the system next encounters its most important test. After the arrangement is complete if it proves to be so complicated that any particular compound cannot be located in a reasonable amount of time the scheme is obviously of little value. Fortunately the Beilstein system renders possible the location of any substance in a few minutes because there is one and only one place for it. Should anyone fail to find it either in the main volume or in the supplement, but two conclusions are possible: (*a*) that the product sought was not described before 1920 or (*b*) that it has been omitted inadvertently.[1] Naturally a scheme embracing over 250,000 compounds, some of them very closely related, would be expected to involve a few peculiarities. These, however, are not very difficult to master.

Index compounds

In the first place all entries are either "index," i.e., parent compounds, or derivatives. If the former they may be located by:

[1] Considering its nature the work is remarkably free from errors.

1. Observing the division and class to ascertain the appropriate volume, then
   a. Consulting the "Inhalt"
   b. Consulting the Index[1]
2. Use of some other aid as
   a. Lange's "Handbook"
   b. The Beilstein "Guide" (see footnote, p. 134)
      List of system numbers, pp. 57–146
      List of common names, pp. 147–216
      Alphabetical class index, pp. 217–246

Derivatives

Derivatives are arranged under their individual index compounds in the order specified on p. 141. *Non-functional* derivatives yield the parent compound by substitution of hydrogen for the non-functioning groups, hence can be classified by mere inspection. *Replacement* derivatives are treated like other functional derivatives, after substitution of oxygen for the S, Se, or Te wherever coupling with an organic compound has occurred through one of these elements. Otherwise all *functional* derivatives are divisible into two types depending upon the nature of the coupling compound. "Hydrosynthesis" yields the index compound and the coupling compound. If it is inorganic the arrangement on p. 140 applies; if organic, the placement will depend upon its position in the scheme. There are, however, certain details about the procedure in hydrosynthesis that require some explanation.

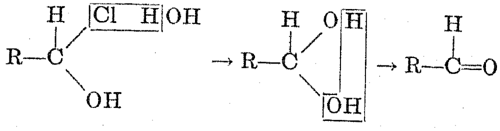
Hydrosynthesis

Whenever functioning groups are attached to different carbon atoms in a compound it is merely polyfunctional and is treated as previously indicated (p. 135). When functional and non-functional groups are similarly located the compound is a non-functional derivative of the functional index compound; e.g., ethylene chlorhydrin ($CH_2Cl \cdot CH_2OH$) is a derivative of ethyl alcohol, a Cl having been substituted for an H in the CH_3 group. If at least two functional groups or one functional plus one or

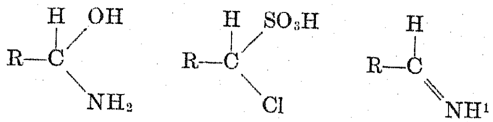
[1] The index has a definite system of arrangement based upon rules for priority among substituents. For details see Vol. 1, pp. 939–44.

more non-functional groups are attached to the same carbon atom three situations may arise.

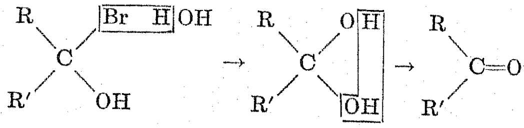
1. The index compound may be an *aldehyde*, since R—CHO is considered equivalent to R—C$(OH)_2$.



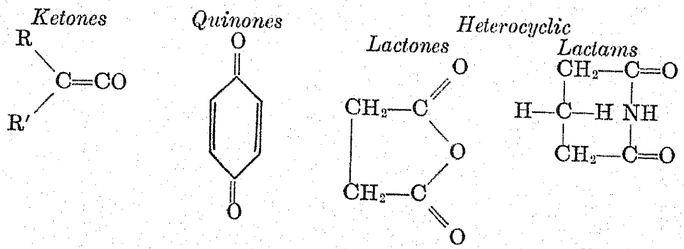
Other examples:



2. The index compound may be a *ketone*, since RR′C═O is considered equivalent to RR′C$(OH)_2$.

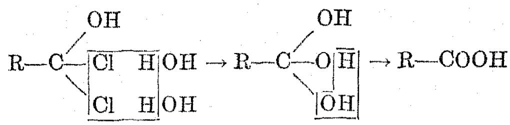


Substitution of R′ for the H attached to C in the illustrations given under No. 1 will give examples of ketones. To the ketone class also belong the following:

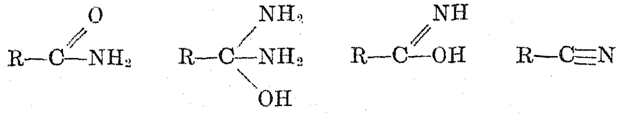


3. The index compound may be a *carboxylic acid*, since RCOOH is considered equivalent to $R{-}C\begin{matrix}OH\\ -OH.\\ OH\end{matrix}$

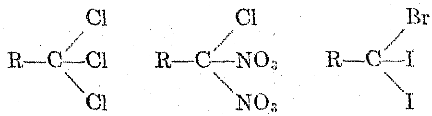
[1] N attached to C by a double or triple bond comes under the rules.



Other examples:



It should be observed that the foregoing rules do not include the case of two or more non-functional groups attached to the same carbon atom with no functional group present. The reason is that such compounds are classified as substitution or non-functional derivatives of the corresponding hydrocarbon.



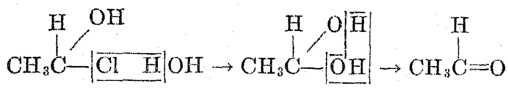
In conclusion, the location of any compound in Beilstein requires, *first*, determination of the division to which it belongs (acyclic, isocyclic, or heterocyclic); *second*, a determination of the index compound; and, *third*, a decision as to the type of substance (hydrocarbon, functional derivative obtained by coupling with an organic or inorganic compound, etc.). When more than one division is involved the last one to be considered is the one to which the compound has been assigned. Similarly when the compound contains different functioning groups it will be found under the last one in the mixed-functions subclass (principle of latest position). Hydrosynthesis, for the purpose of ascertaining the index compound in complex substances, must not disturb ring structures or carbon-to-carbon linkages. When organic coupling compounds are involved, the OH from the HOH goes to the coupling compound. When inorganic coupling compounds are concerned, the H from the HOH goes to the coupling compound. The final products of all hydrosynthetic operations must be index or coupling compounds. The following illustrations of the process may be of assistance.

Examples:

1. H OH

CH_3C—Cl

This compound is acyclic and has a functional plus a nonfunctional group attached to one carbon. Hence by hydrosynthesis acetaldehyde is the index compound. It was coupled with an inorganic halogen acid to give the product sought.



Four paths may now be followed all leading to the same place.

a. The index compound is an acyclic, "oxo-verbindung" therefore in Vol. I. (See analytical table on pp. 129–33 of this manual or the backs of the volumes themselves.) Page VII of the "Inhalt" shows that "*Oxo-verbindungen*" start on text p. 551. On p. VIII *acetaldehyde* is found to start on text p. 594, its *functional derivatives* on p. 603. Derivatives involving *inorganic coupling compounds* are first encountered on p. 605, and those of the *inorganic halogen acids* on p. 606, where the desired substance $CH_3CH{\cdot}OH{\cdot}Cl$ is located.

b. Find the word "acetaldehyd" in the index at the back of Vol. I. Turn to the page there indicated, i.e., 594. Thence proceed as in *a.* If the indexed name "Acetaldehyd hydrochlorid" is known it will give the text p. 606 directly.

c. Using Prager's "Guide"[1] find acetaldehyde in the "Verzeichnis der Systemnummern" under "Oxo-verbindungen," system No. 77, p. 58. Then find system No. 77 in Vol. I on p. 594, and thereafter proceed as in *a.* The "Verzeichnis von Trivialnamen" (list of common names) starting on p. 146 of the "Guide" would be equally useful.

d. Find acetaldehyde in Lange's "Handbook."[2] Entry No. 5 refers to Beilstein, Vol. I, p. 594. Thereafter proceed as in *a.*

2. H H

H—C—C—OH

Cl H

While this compound is an isomer of the one previously considered it will not be found in the same place because

[1] See footnote, p. 134.

[2] LANGE, N.A., "Handbook of Chemistry," Handbook Publishers, Sandusky, Ohio, 2d ed., 1937. There is, on pp. 264–496, a table of "Physical Constants of Organic Compounds" which contains a reference to Beilstein IV for each of the 4,452 compounds listed.

the functional and non-functional groups are not on the same carbon.

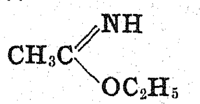
a. Replacing the non-functional Cl with H the index compound is obviously ethyl alcohol, an acyclic, "mono-oxy Verbindung." In Vol. I, "Inhalt" p. VI under "Alkohols" is found "Ethyl," and under that "Substitutionsprodukte" which refers to text p. 336. With that page as a starting point the desired compound is on 337.

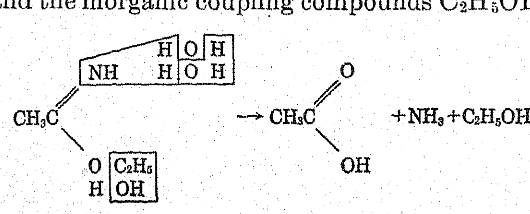
b. Find "Athanol" or "Äthylalkohol" in the index of Vol. I. The reference in either case is to p. 292. Then by turning the pages beyond 292 the right one, 337, ultimately will be reached. If the names "Chlor-äthanol, Glykolchlorhydrin, or Äthylenchlorhydrin" are used, they will refer directly to p. 377.

c. In the "Guide," p. 57, below system No. 20, "Äthylalkohol," will be found "22) β-Substitutionsprodukte des Äthylalkohol." This refers to Vol. I, p. 336. The desired product is on the next page of that volume.

If "Alkohol" is looked for in the list of common names, p. 148 of the "Guide," a reference to system No. 20, Vol. I, p. 292, is obtained which gives a starting point not as close to the desired substance as the preceding method.

d. In Lange's "Handbook," p. 368 No. 1987, the reference is also to Vol. I, p. 292. Under "Ethylene Chlorohydrin" (p. 372, compound No. 2063) will be found the direct reference, Vol. I, p. 337.

3  This compound has two functional groups attached to the same carbon. Hydrosynthesis yields a monocarboxylic acid as the index compound which has been combined with the organic and the inorganic coupling compounds C_2H_5OH and NH_3



to form the desired ethyl ester of imino acetic acid. It should be noted in this example that the $=NH$ is not considered a main class group but is from the inorganic coupling compound NH_3.

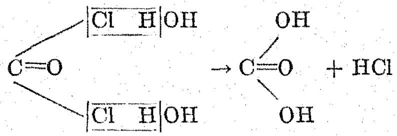
a. Acyclic monocarboxylic acids are in Vol. II. The "Inhalt," p. III, has the entry "Essigsäure," p. 96. Farther along, beyond the organic functional derivatives, because of the principle of latest position, will be found "Ammoniak-derivate der Essigsäure," text p. 175. On this page, acetimide and its derivatives are first encountered. The search ends on p. 182.

b. Find "Essigsäure-amid" in the index of Vol. II. This will give the text p. 175. Proceed from there as already indicated. If the entry "Acetimino-äthyläther" is consulted the reference will be direct to p. 182.

c. On p. 59 of the "Guide" will be found "Essigsäure" under system No. 158. In the common-name index on p. 168 under the same entry will be found the additional information, Vol. II, p. 96. Either will ultimately lead to the desired compound.

d. The closest reference in Lange's "Handbook" (p. 266, No. 13) is to acetamide which gives Vol. II, p. 175.

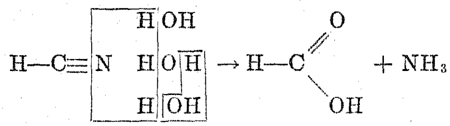
4. **$COCl_2$** Carbonyl chloride or phosgene is readily found by name in either Lange's "Handbook" or the common-name index of the "Guide." Without these aids the only difficulty is to ascertain which volume of Beilstein to examine. This is readily determined by hydrosynthesis.



The index compound is hydroxyformic acid or carbonic acid, an "Oxycarbonsäure" which has been united with an inorganic halogen acid. This directs the search to Vol. III, where the "Inhalt," p. III, under "Oxy-carbonsäuren . . . Kuppelungsprodukte aus Kohlensäure" contains the word "phosgen" and refers to text p. 9. After the couplings involving one functional OH have been passed the first entry employing both of them is the desired compound. It is on p. 13.

If the "Inhalt" is ignored both of the names "phosgen" and "carbonyl chloride" will be found in the index, each referring to p. 13.

5. **KCN** According to the rules (p. 145) when an N is thrice bound to C the index compound is an acid, in this case formic acid

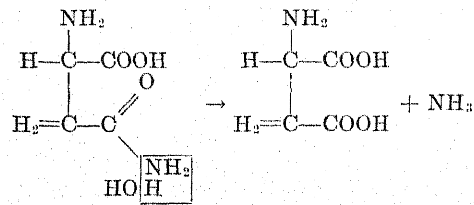


which has been coupled with ammonia to yield a nitrite—"formonitrite," "Blausäure," or hydrocyanic acid. The compound desired is the potassium salt of that acid.

a. Since a simple acid is involved, Vol. II is indicated. In the "Inhalt," p. 111, under "Monocarbonsäure" are found the names "Formonitrite, Cyanwasserstoff, Blausäure" and the text p. 29 is given. KCN is on p. 41, under salts.

b. In the index of Vol. II "Cyan-kalium" is entered together with the reference to p. 41.

6. **$COOH{\cdot}CH{\cdot}NH_2{\cdot}CH_2CO{\cdot}NH_2$** This compound, rewritten, is seen to be the amide of a dicarboxylic acid containing a functional NH_2 group



The index compound is aminosuccinic acid which has been coupled with NH_3. This index compound comes under the arrangement covering amines associated with other functioning groups (see p. 139). The classification is "amino derivative of a dicarboxylic acid."

a. According to the foregoing statement Vol. IV is indicated. The "Inhalt," p. VI, contains the entry "Aminoderivate der Dicarbosäure, $C_nH_{2n-2}O_4$." This is the empirical formula of succinic acid, so the search is continued from p. 469 to p. 471 where, under $C_4H_6O_4$, the desired compound, d-asparagin, is the last one on the page.

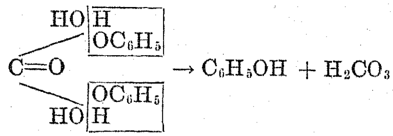
b. The index in Vol. IV contains the entry "Asparagin" and refers directly to p. 471.

c. In the "Guide" p. 63, the system-number list, refers to amino dicarboxylic acids under system No. 372. The common-

name list, p. 151, refers to Vol. IV, p. 471 under the entry "Asparagin."

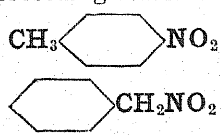
d. Lange's "Handbook," p. 286, No. 387, refers to the laevo but not to the dextro form.

7. $\mathbf{C_6H_5O{\cdot}CO{\cdot}OC_6H_5}$ The only problem in finding the compound diphenyl carbonate is determining the volume to consult. Hydrosynthesis reveals that the index compound is phenol which has been coupled with carbonic acid.



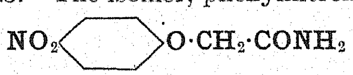
a. Since phenols are discussed in Vol. VI, an examination of the "Inhalt," p. IV, reveals "Kupplungsprodukte aus Phenol und Carbonsäure" which start on p. 152. The desired compound is on p. 158.

b, c, d. Details will be omitted, since they are obvious from the preceding statements.

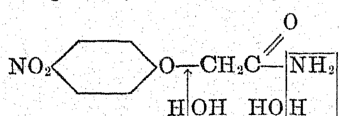
8. 

These compounds are isomers. They will be found in the same place, but the ring-substitution product is considered before that involving the side chain.

Paranitrotoluene is a substitution derivative of toluene. Turning to the "Inhalt" of Vol. V under "Kohlenwasserstoffe, C_nH_{2n-6}," will be found "Toluol," then "Substitutionsprodukte des Toluols, 290." The halide compounds are first, then come ortho- and meta-nitrotoluene with the para derivative last on p. 323. The isomer, phenylnitromethane, follows on p. 325.

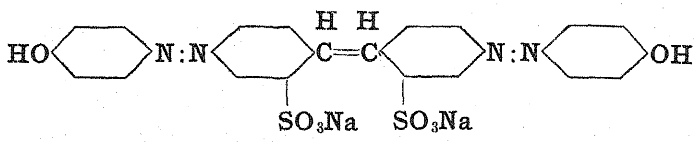
9. 

This is a derivative of paranitrophenol and hydroxyacetic acid. Isocyclic hydroxy compounds are in Vol. VI. Paranitrophenol is on p. 226, the hydroxyacetic acid

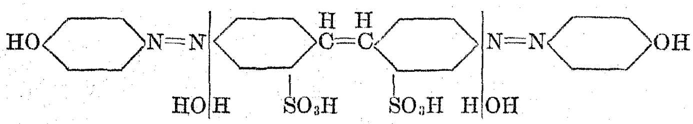


derivative at the top of p. 234, and the desired compound "4-nitro-phenoxyessigsäure-amid" a few lines below.

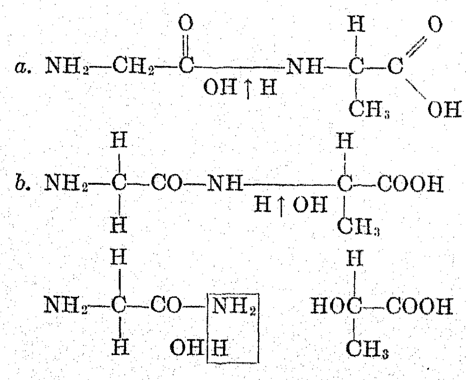
10. $\mathbf{C_6H_5SO_2NCl_2}$ Benzenesulfonic acid dichloramide is a third order derivative of the index compound benzenesulfonic acid coupled with ammonia which indicates that Vol. XI will contain the compound sought. It is on p. 49.

11. 

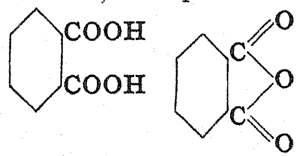
If the name of this dye, "brilliant yellow," is known it can be found quickly by consulting the common name index of the "Guide" (p. 154) where the system No. 2156 is given. This leads directly to Vol. XVI, p. 290, or to the index of the same volume which shows that brilliant yellow is on p. 291. Should the common name be unknown hydrosynthesis shows that the compound is an azo derivative of a disulfonic acid, $(C_nH_{2n-16}O_6S_2)$. Hence the "Inhalt" of Vol. XVI will serve as a guide.



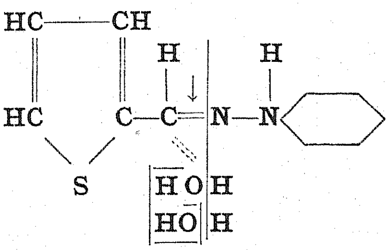
12. $\mathbf{NH_2{\cdot}CH_2{\cdot}CONH{\cdot}CHCH_3COOH}$ Whenever hydrosynthesis can be effected in more than one way that method is always chosen which yields an index compound entered later than any of those obtained by other methods. The foregoing substance may be decomposed in two ways:



Since $CH_3 \cdot NH_2 \cdot CHCOOH$, alpha aminopropionic acid or alanine, as obtained in *a*, occurs last in the system, this index compound is the one under which the original substance will be found. It is in Vol. IV, p. 381. Glycyl-*d*-alanine, the substance desired, is on p. 483.

13. 

Even though these two compounds are closely related, according to the system phthalic acid is an isocyclic dicarboxylic acid, therefore in Vol. IX, p. 791; whereas phthalic anhydride is a heterocyclic diketone, hence in Vol. XVII, p. 469.

14. 

Hydrosynthesis at the point indicated, which, according to the rules, is the only one permissible, reveals the fact that thiophene aldehyde was united with phenylhydrazine to form the compound sought. Since the index compound is a replacement derivative of furfural, that substance or its parent, furane, is first located in Volume XVII. Thereafter the "Inhalt" or the index will lead to p. 286. The table of contents lists "Thiophenaldehyd und Derivate," p. 285, under "Monoxo-Verbindungen, $C_nH_{2n-6}O_2$." The index gives both "Thiophen-aldehyde" and "Thiophen-aldehydphenylhydrazon."

Space limitations make it impossible to consider the other books of organic chemistry in any detail. The balance of this chapter will be devoted, therefore, to two lists: (*a*) the more advanced reference books of the field with a few comments as to their scope or usefulness and (*b*) the more important laboratory aids with some indication of their value.

Advanced treatises

GRIGNARD and BAUD (ed.), "Traité de chimie organique," Masson & Cie., Paris, 1935– . The fourth volume was published in 1936; eleven more have been planned. After the

death of Grignard, Professors R. Locquin and G. Dupont were selected to complete his share of the work.

Each volume consists of papers on various phases of organic chemistry by eminent French scientists. Volumes I and II form a general introduction to the series; III deals with aliphatic and cyclic hydrocarbons; and IV, with cyclic hydrocarbons. A few of the titles follow.

I. Organic Analysis. Liquid Crystals. Distillation. Nomenclature.
II. Optical Properties of Organic Compounds. Raman Effect. Parachor. Mechanism of Reactions. Free Radicals. Catalysis.
III. Saturated Hydrocarbons. Halogen Derivatives. Monocyclic Terpenes.
IV. The Benzene Ring. Halogen Ring and Side Chain Derivatives. Technical Uses of Petroleum Products.

Meyer and Jacobson, "Lehrbuch der organischen Chemie," Walter de Gruyter Co., Berlin and Leipzig, 2d ed., 2 vols., 1907– . Edited by Paul Jacobson. The first volume of this edition, covering aliphatic compounds, was published in two parts: Part 1—1907 (last reprinted in 1922), Part II—1913 (last reprinted in 1923). The second volume, discussing aromatic and naturally occurring compounds, was started in 1914. Five sections were finished by 1929, but, aside from a promise to complete the work promptly, nothing further has been done. For many years this was considered the best textbook of organic chemistry.

The compounds are discussed according to types with a good description of every important individual in each group. Adequate references to the original literature are given. The material published thus far covers over four thousand pages.

Cohen, J.B., "Organic Chemistry for Advanced Students," Edward Arnold & Co., London, 4th ed., 2d printing 1923–4. Part I, Reactions; II, Structure; III, Synthesis. This text is much shorter than that by Meyer and Jacobson but very good. There are many references to original sources. Each part, or volume, has an author and a subject index. The preface calls attention to the new subject matter included in this edition

and also states that natural dyestuffs and synthetic drugs are not considered.

RICHTER, V.v., "Organic Chemistry or Chemistry of the Carbon Compounds," P. Blakiston's Son & Co., Philadelphia. New translation and revision of the 12th German ed. Vol. I, Aliphatic Compounds, by E.N. Allott, 1934. Volume II, Carbocyclics, and Vol. III, Heterocyclics, are in preparation. The German edition of Vol. II, edited by R. Anschütz, was published in 1935. This is a well-established work as attested by 12 German, 3 American, and 3 English editions. The new version follows the systematic and concise treatment of the previous issues. There are many references to the original literature. Some of the newer concepts have been introduced, e.g., Pregl's microanalysis and the electronic theory of valency.

SCHLENK and BERGMANN, "Ausführliches Lehrbuch der organischen Chemie," Franz Deuticke, Vienna, Vol. I, 1932. This volume covers the aliphatic series. It stresses fundamental principles and reactions, ignoring detailed discussions of individual compounds or industrial processes. The structure of complex substances is considered in some detail, e.g., cellulose, rubber, and hemoglobin.

SCHMIDT, JULIUS, "Textbook of Organic Chemistry," Gurney & Jackson, London. 3d English ed. revised by H.G. Rule, 1936. This is the latest translation of Schmidt's well-known "Kurzes Lehrbuch der organischen Chemie."

KARRER, PAUL, "Lehrbuch der organischen Chemie," Georg Thieme Verlag, Leipzig, 4th ed. 1936.

HÜCKEL, WALTER, "Theoretische Grundlagen der organischen Chemie," Akademische Verlagsgesellschaft, Leipzig, Vols. I and II, 1931. "A careful analysis of the experimental foundations for the present views concerning the nature of the organic compounds." This work is more up-to-date than Hinrich's "Theories of Organic Chemistry" (trans. by Johnson and Hahn).

Elementary textbooks

CONANT, J.B., "Chemistry of Organic Compounds," The Macmillan Co., New York, 1933.

HOLLEMAN, A.F., "Textbook of Organic Chemistry," Walter de Gruyter Co., Leipzig, 20th ed. by F. Richter, 1935.

LOWY and HARROW, "Introduction to Organic Chemistry," John Wiley & Sons, New York, 4th ed., 1936.

LUCAS, H.J., "Organic Chemistry," American Book Co., New York, 1935.

MOORE, F.J., "Outlines of Organic Chemistry," John Wiley & Sons, New York, 4th ed. revised by W.T. Hall, 1933.

NORRIS, J.F., "Principles of Organic Chemistry," McGraw-Hill Book Co., New York, 3d ed., 1931.

PERKIN and KIPPING, "Organic Chemistry," J.B. Lippincott Co., Philadelphia. "Entirely new edition" by F. Stanley Kipping and F. Barry Kipping, 1932.

Dyes

THORPE and LINSTEAD, "Synthetic dyestuffs . . . ," Charles Griffin & Co., London, 7th ed., 1933.

MEYER, FRITZ, "Chemie der organischen Farbstoffe," Julius Springer, Berlin, 3d ed., Vol. I, 1934; II, 1935. The first volume covers commercial (synthetic) dyes, and the second deals with natural dyestuffs.

SHREVE, R.N., "Dyes Classified by Intermediates," Chemical Catalog Co., New York, 1922.

ROWE, F.M. (ed.), "Colour Index," Society of Dyers and Colourists, Bradford, Yorkshire, England, 1st ed., 1924; 1st suppl., 1928. Similar to Schultz, *q.v.*

SCHULTZ, GUSTAV, "Farbstoff-tabellen," Weidmannsche Buchhandlung, Berlin, also Akademische Verlagsgesellschaft, Leipzig, 7th ed. revised by L. Lehman, 1929– . Supplement to Vol. I, 1934. A systematic arrangement of all commercially important organic dyes covering various names, constitution, preparation, discovery, references, and reactions.

Miscelleneous general surveys

STEWART, A.W., "Recent Advances in Organic Chemistry," Longmans, Green & Co., New York, 6th ed., 2 vols. 1931. Volume II was reprinted in 1936 with an additional section on

biochemistry by H. Graham. "A survey of numerous fundamental problems" both constitutional and theoretical. This treatise "is not intended to serve as a reference book, but to furnish a general survey of those fundamental principles which underlie the modern developments of this branch of chemistry."

Schmidt, Julius, "Jahrbuch der organischen Chemie," Franz Deuticke, Vienna, Vol. 1, 1907—Vol. 19, 1932. Each volume summarizes the advances of the year, excluding dyes and patents; gives a list of the important books published and the eminent investigators who died during the period covered.

Schmidt, Julius (ed.), "Chemie in Einzeldarstellungen," Wissenschaftliche Verlagsgesellschaft, Stuttgart, Vol. I, 1912; Vol. XVII, 1934. This valuable series of monographs includes the titles listed in Table 37.

Table 37.—Some Monographs in the Series "Chemie in Einzeldarstellungen"

Volume	Date	Subject and author
I	1912	Ketenes, by Staudinger
IV	1913	Handbook of organic arsenic compounds, by Bertheim
V	1913	Hydrazine, by Wieland
VI	1914	Triphenylmethyl, by Schmidlin
X	1920	Physical properties and chemical constitution, by Kauffmann
XIV	1929	Commercial resins, by Schreiber and Sändig (Good patent survey)
XV	1931	Organic materials used for electrical insulating purposes, by Stäger
XVI	1932	Organometallic Compounds. Pt. 1, Magnesium Compounds, by Runge
XVII	1934	Organometallic Compounds. Pt. 2, by Schmidt

Heilbron, I.M. (ed. in chief), "Dictionary of Organic Compounds," Oxford University Press, New York, Vol. I, 1934; Vol. II, 1936; Vol. III, 1938. This compilation, arranged in alphabetic order, according to the common name of the compound, aims to include, for each substance, its source, physical properties, chemical properties, and a reference to the best method for preparation.

LIPPMANN, E.O.v., "Zeittafeln zur Geschichte der organischen Chemie," Julius Springer, Berlin, 1921. A chronological list of important events from 1500 to 1890.

IPATIEV, V.N., "Catalytic Reactions at High Pressures and Temperatures," The Macmillan Co., New York, 1936. Ipatiev summarizes his own work in the field.

SAUNDERS, K.H., "The Aromatic Diazo-compounds and Their Technical Applications," Edward Arnold & Co., London, 1936.

SIDGWICK, N.V., "Organic Chemistry of Nitrogen," Oxford University Press, New York, new ed. by Taylor and Baker, 1937.

WEISSBERGER and PROSKAUER, "Organic Solvents," Oxford University Press, London, English trans. by R.G.A. New, 1935. Physical constants and methods of purification are considered.

Laboratory guides

HOUBEN, J. (ed.), "Die Methoden der organischen Chemie (Weyls Methoden)," Georg Thieme, Leipzig, 4 vols., 3d ed. Vols. I to II, 1925; Vol. III, 1930; 2d ed., Vol. IV, 1924.

"A very extensive treatise on organic chemistry written not merely—or even primarily—for those who need to know something about organic compounds, but for all those who have occasion to work with them. . . . It comes from, and it is intended for the workshop, but its authors have not been content with merely providing directions for mechanical experimentation." A brief and inadequate summary of the volumes is given in Table 38.

LASSAR-COHN, "Organic Laboratory Methods," Williams & Wilkins Co., Baltimore. Translation from the "General Part" of the 5th German ed., by Ralph E. Oesper, 1928. The original compilation in German by Lassar-Cohn consists of a small (350 pp.) "General Part" and a large (1,500 pp.) "Special Part." The former deals with general operations, the latter with specific preparations as examples of general synthetic methods. The fifth edition was published shortly after Professor Lassar-Cohn's death in 1922. The only portion available in English is Dr. Oesper's translation of the first part.

VANINO, L. (ed.), "Handbuch der präparativen Chemie," F. Enke, Stuttgart, 2d ed., Vol. I, Inorganic, 1921; Vol. II, Organic, 1923. Specific directions are given for the preparation

of about a thousand organic compounds. General operations or theoretical problems are not considered.

TABLE 38.—SUMMARY OF HOUBEN'S "METHODEN"

Volume	Date	Contents
I	1925	General part. Analysis and general operations Elementary analysis Micro analysis Crystallographic methods Determination of nature of dyes . . . Appendices 1. Solubility of inorganic salts in water 2. Solubility of inorganic salts in ethyl alcohol, methyl alcohol, and ether
II	1925	Special part Oxidation Condensation Reduction Electrochemical methods Catalysis High-pressure reactions . . .
III	1930	Special part Discussions of various groups: hydroxyl, aldehyde, ketone, carboxyl . . .
IV	1924	Special part Similar to Vol. III: nitro group, amino, azo, etc. Organometallic compounds . . .

GATTERMANN-WIELAND, "Laboratory Methods of Organic Chemistry," The Macmillan Co., New York. Translation of the 24th German ed. by W. McCartney, 1937. The first edition of "Gattermann" was published in 1894; the 21st to 24th of the German text were prepared by H. Wieland, the latter edition now being available in English as described above. The book is an excellent laboratory manual for advanced students. Specific directions are given for typical syntheses; then the general applications of each process are considered.

"Organic Syntheses," John Wiley & Sons, New York, 1921– . Editorship varies. "An annual publication of satisfactory methods for the preparation of organic chemicals." This series was started in 1921 by Roger Adams at the University of Illinois. Seventeen annual reports and one collective volume have been published. Each annual issue contains tested directions for the preparation of about thirty compounds in approximately 500-gram lots. Collective Vol. I is a summary

of the methods in annual Vols. 1 to 9 inclusive. It is also available in French.

GROGGINS, P.H., "Unit Processes in Organic Syntheses," McGraw-Hill Book Co., New York, rev. 1938.

Organic nomenclature

Aside from the discussion in each volume of Beilstein IV and the annual index of Chemical Abstracts the following specific articles may be cited:

PATTERSON and CURRAN, *J. Am. Chem. Soc.,* **39,** 1623–38 (1917).

HOLLEMAN (as chairman of the committee), *Rec.trav.chim.* [4] **48,** 641–51 (1929).

Idem, Helv.Chim.Acta **14,** 868–75 (1931); or *J.Chem.Soc.,* **1931,** 1607–16.

VERKADE, P.E., *Rec.trav.chim.,* [4] **51,** 185–217 (1932). A detailed article.

PATTERSON (trans.), *J.Am.Chem.Soc.,* **55,** 3905 (1933). A translation of the French report with comments by Patterson.

Organic technology

Many outstanding surveys belonging to this division have been published as monographs in the various technical series. Some of these have been mentioned in Table 16, p. 86. The following list is given merely to call attention to a few of the more important compilations in some of the rapidly changing fields.

Cellulose

BROWN and CRAWFORD, "Survey of Nitrocellulose Lacquer," Chemical Catalog Co., New York, 1928. Largely a bibliography including patents.

DOREE, C., "Methods of Cellulose Chemistry," D. Van Nostrand Co., New York, 1933.

WORDEN, E.C., "Technology of Cellulose Ethers," The Chemical Catalog Co., New York, 5 vols., 1933.

Paper

HUNTER, D., "Papermaking through Eighteen Centuries," W.E. Rudge, New York, 1930.

Perfumes

MANN, H., "Die moderne Parfümerie," Julius Springer, Berlin, 4th ed. ed. by F. Winter, 1932.

POUCHER, WILLIAM, "Perfumes, Cosmetics, and Soaps," D. Van Nostrand Co., New York, 5th ed., 1936.

Petroleum

BELL, H.S., "American Petroleum Refining," D. Van Nostrand Co., New York, 2d ed., 1930.

Resins, synthetic

ELLIS, C., "The Chemistry of Synthetic Resins," Reinhold Publishing Corp., New York, 2d ed., 1935.

"British Plastics Year Book, 1937," Plastics Press, London, 1937. This is the seventh volume of "the handbook and guide to the plastics industry."

Rubber

BEDFORD and WINKELMANN, "Systematic Survey of Rubber Chemistry," Chemical Catalog Co., New York, 1923.

HAUSER, E.A., "Latex," Chemical Catalog Co., New York. Trans. by W.J. Kelly, 1930.

MARCHIONNA, F., "Latex and Its Industrial Applications," Rubber Age Publishing Co., New York, 1933.

Soap

MARTIN, GEOFFREY, "The Modern Soap and Detergent Industry," C. Lockwood & Sons, London, 2 vols., 1932. Vol. I, Theory and Practice; Vol. II, Manufacture of Special Soaps and Detergent Compositions.

Sulfur

BORGSTROM, BOST, and BROWN, "Bibliography of Organic Sulfur Compounds (1871–1929)," American Petroleum Institute, New York, 1930.

Terpenes

SIMONSEN, J.L., "The Terpenes," The Macmillan Co., New York, Vol. I, 1931; Vol. II, 1932.

ANALYTICAL CHEMISTRY

"If you can measure that of which you speak, and can express it by a number, you know something of your subject; but if you cannot measure it, your knowledge is meagre and unsatisfactory." LORD KELVIN

The analytical chemist is a manufacturer of pure chemicals on a laboratory scale. His object is to identify materials, determine their composition, or insure their uniformity. He is interested in the physical and chemical properties of substances, especially their peculiarities and distinguishing characteristics. His sources of information will naturally be books on inorganic, organic, and physical chemistry. A large amount of literature is also available dealing more specifically with analytical problems. This literature may be separated into two categories, one concerned with identification or qualitative analysis, and the other with determination or quantitative analysis. Both are subdivided according to methods and instruments employed. There are books on inorganic, organic, microscopic, and spectroscopic methods of identification; and on gravimetric, volumetric, colorimetric, electrometric, and spectrographic procedures for quantitative work. Classification may also be based upon the material discussed, e.g., brass, foods, steel, paint.

Use

While a few comprehensive surveys exist there is nothing in the field of analytical chemistry to compare with Beilstein, "The bible of organic chemistry." Consequently a search for analytical information differs only slightly in technique from that described on pp. 119–21. A chemist is usually asked to make a partial or complete analysis of a given product. His initial library search will be for methods covering the product as a whole. The nature of the sample will indicate the books to be consulted: perhaps Allen for organic, Lunge for inorganic, or the more specialized treatises dealing with a single type of

commodity. If nothing helpful is found, methods for the various constituents can surely be located in Rüdisüle, Hillebrand and Lundell, or other general reference works. In any case it is well to examine these sources before turning to the journals (p. 165).

Qualitative or quantitative methods must take into consideration the amount of an element present and the probable interferences. For any operation the analyst should know the main reaction, possible side reactions, optimum conditions of temperature, acidity, reagents, etc. In the case of a precipitate he should know its solubility, form (crystalline or gelatinous), composition, and other properties important in analytical work. If economic features are involved a gravimetric method, generally speaking, is less time consuming than a volumetric when only one sample is to be analyzed, while a volumetric procedure is preferable for routine work. The cost of reagents and any special equipment is also an important item.

When consulting the literature it is well to remember that authors with years of experience "at the bench" frequently give better directions than compilers who are unable to point out essential details. On the other hand, adepts may omit important points, assuming that they are too well known to be mentioned. It is advisable, therefore, when using a method for the first time, to become acquainted with it through the analysis of samples of known composition. Wherever instruments are involved their construction, operation, and limitations should be known. If results are unsatisfactory, the worker before condemning the method should make sure that he has not omitted an essential step and has understood the purpose of every operation as well as the test for its effectiveness.

Official methods

In the commercial world analytical procedures are divided into two groups, official and non-official. An official method is one that has been carefully studied and approved by a representative group of experts who have worked out specific directions for its use (cf. p. 178). Such a procedure is used in connection with the purchase and sale of commodities to avoid misunderstanding and disagreement concerning the quality of the goods. If

analytical details are not mentioned in the contract the chemist should use the official process whenever one is available. For example, when magnesium carbonate, U.S.P., is being purchased he should follow the directions given in the latest edition of the United States Pharmacopoeia. The publications of the Association of Official Agricultural Chemists should be consulted for guidance in the determination of "poisonous" metals in foodstuffs or the adulteration of beverages. Additional sources of information are mentioned on pp. 178–81.

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Other bibliographies

Crane and Patterson, pp. 372–3.

Griffin, pp. 887–895 (see p. 174 of this text).

Jenkins and Du Mez, "Quantitative Pharmaceutical Chemistry," McGraw-Hill Book Co., New York, 2d ed., 1937. Texts, calculations, general references, drug and food analysis, etc.

Mellon, pp. 118–20, 132.

National Research Council Bull. 50, 71, 86. Look under "Analytical Chemistry."

Willard and Furman, pp. 8–13 (see p. 175 of this text).

Fehling's "Encyclopedia" contains many good bibliographies on the individual elements.

Journal of Analytical Chemistry for 1886–90 (Vols. 1 to 5) contains several bibliographies of analytical chemistry by H.C. Bolton. These are good starting points for complete surveys.

Serial publications

Zeitschrift für analytische Chemie. This journal was started in 1862 by C. Remigius Fresenius because he felt that not enough space was available in the existing periodicals for articles on analysis. Two main dvisions are maintained in each issue: (*a*) original articles and (*b*) abstracts. The latter include general analytical methods and apparatus, inorganic analysis, organic analysis, and special methods. Down to Vol. 62 (1923) there was but one volume annually. In that year the number started to increase, reaching a maximum of four volumes for

1927 where it has remained. There are annual and decennial author and subject indexes.

The Analyst. This is the official organ of the British Society of Public Analysts. It was started in 1877 and has appeared in one volume a year ever since.[1] There are annual and cumulated indexes. The first of the latter covers twenty years, the others ten each.

Annales de chimie analytique et de chimie appliquée. This journal has been issued since 1896 in one volume a year.

Industrial and Engineering Chemistry, Analytical Edition. Started in 1929 apparently to relieve some of the pressure on the parent journal, this offspring should maintain an important place in chemical literature. It was issued quarterly until 1937. Since then it has appeared monthly.

There are some other journals devoted solely to analysis, and many of a more general nature carry analytical sections. Their number is too large to permit individual mention here. The abstract divisions in Chemical Abstracts, Chemisches Zentralblatt, British Chemical Abstracts, and the Zeitschrift für analytische Chemie will furnish sufficient clues for anyone desiring to compile a list of them.

Margosches, B.M., "Die chemische Analyse," F. Enke, Stuttgart, 1907– . A series of monographs on chemical, technical, and physico-chemical analysis edited by Margosches until his death in 1928,[2] there after by William Böttger. A detailed list of this series follows:

1. The use of Hydrazine in Analytical Chemistry. J. Schmidt (1907).
2. Analytical Methods for Zinc, Especially Ores. H. Nissenson (1907).
3. Physical Chemistry as a Foundation for Analytical Chemistry. W. Herz (3d ed., 1930).

4–5. Rapid Methods of Electrolytic Analysis. A. Schleicher (2d ed., 1926).

6. Analysis of Iron Tannate Colors. F.W. Hinrichsen (1909).

[1] Except in 1878, when Vols. 2 and 3 were issued.
[2] For portrait and biographical sketch see Vol. 29 of the series.

7. Analytical Methods for Hydrogen Peroxide. L. Brickenbach (1909).

8–9. Analysis of Milk and Its Products. K. Teichert (2d ed., 1927).

10. Determination of Bismuth. L. Moser (1909).

11–12. Catalysis. Role of Catalysts in Analytical Chemistry. G. Woker (1911).

13. Status and Trend of Analytical Chemistry. William Böttger (1911).

14–15. Analysis of Rare Earths. Meyer and Hauser (1912).

16. Determination of Nickel and Cobalt. H. Grossmann (1913).

17–18. Determination of Arsenic, Antimony and Tin. H. Wölbling (1914).

19–20. Detection of Organic Compounds. R. Rosenthaler (2d ed., 1923).

21–22. Catalysis. Inorganic Catalysts. G. Woker (1915).

23–24. Catalysis. Hydrolyzing Ferments. G. Woker (1924).

25. Rapid Iodine Number Methods. B.M. Margosches (1927).

26. Visual Conductivity Titrations. Jander & Pfundt (2d ed., 1934).

27–28. Catalysis. Biological Catalysts. G. Woker (1931).

29. Outstanding Research Methods. L.W. Winkler (1931).

30. Mathematics and Mathematical Aids in Analytical Chemistry. O. Liesche (1932).

31. Analytical Methods for Cast Iron, Steel and Ferro-alloys. J. Kassler (1932).

32. Identification of Organic Compounds; Especially Medicinals. L. Ekkert (1933).

33. New Volumetric Methods. Brennecke, Furman, Fajans, and Lang (1935).

34. O-Hydroxyquinoline "Oxine." R. Berg (1935).

35. Research Methods. L.W. Winkler (Pt. 2, 1936).

36. Analytical Chemistry of the Noble Metals. A. Wogring (1936).

37. Organic Precipitating Agents in Quantitative Analysis. William Prodinger (1937).

Qualitative analysis, inorganic

Böttger, William, "Qualitative Analyse," W. Engelmann, Leipzig; 4th to 7th ed., 1925. Very good.

Fresenius-Mitchell, "Introduction to Qualitative Chemical Analysis," John Wiley & Sons, New York, 1921. A translation of the seventeenth edition of Fresenius by C.A. Mitchell. An excellent reference book. It contains data regarding a few organic compounds.

McAlpine and Soule, "Qualitative Chemical Analysis," D. Van Nostrand Co., New York, 1933. This book is based upon the well-known text by Prescott and Johnson. The outstanding features are the systematic arrangement and detailed treatment of the subject matter.

Noyes and Bray, "System of Qualitative Analysis for the Rare Elements," The Macmillan Co., New York, 1927. The results of over twenty years' work in the field of qualitative analysis are given in this book. It covers the common and rarer elements. A valuable feature is the inclusion of experimental data upon which recommended separations are based.

Treadwell and Hall, "Analytical Chemistry," Vol. I, Qualitative Analysis. John Wiley & Sons, New York, 8th ed., 1932.

Yoe, J.H., "Chemical Principles," John Wiley & Sons, New York, 1937.

Brady, G.S., "Materials Handbook," McGraw-Hill Book Co., New York, 2d ed., 1931. The qualitative composition of many common alloys will be found in this volume.

"A.S.T.M. List of Alloys," American Society for Testing Materials, Philadelphia, 1931. The trade name and composition are given for several hundred alloys.

Qualitative analysis, organic

Clarke, H.T., "Handbook of Organic Analysis," Edward Arnold & Co., London, 1920.

Kamm, O., "Qualitative Organic Analysis," John Wiley & Sons, New York, 2d ed., 1933.

Mulliken, S.P., "Identification of Pure Organic Compounds," John Wiley & Sons, New York, 1904–22. 4 vols.

Porter, Stewart and Branch, "Methods of Organic Chemistry," Ginn and Co., Boston, 1927.

Shriner and Fuson, "Systematic Identification of Organic Compounds," John Wiley & Sons, New York, 1935.

Staudinger-Braunholtz, "Introduction to Qualitative Organic Analysis," D. Van Nostrand Co., New York, 1925.

Qualitative analysis, special methods

Behrens-Kley, "Microchemische Analyse," Leopold Voss, Leipzig, 3d ed. in two parts, 1915. Part I deals with general principles, and Part II consists of a series of tables for the systematic detection of minerals.

Chamot and Mason, "Handbook of Chemical Microscopy," John Wiley & Sons, New York, Vol. I—1930; Vol. II—1931. Volume I deals chiefly with the microscope and its accessories. In Vol. II will be found a detailed discussion of qualitative microscopy.

Danckwortt, P.W., "Lumineszenz-Analyse," Akademische Verlagsgesellschaft, Leipzig, 3d ed., 1934. A bibliography of several hundred references supplements the text.

Feigl, F., "Qualitative Analyse mit Hilfe von Tüpfelreaktionen," Akademische Verlagsgesellschaft, Leipzig, 2d ed., 1934. This is undoubtedly the foremost book on the application of organic reagents to the detection of metals.

Radley and Grant, "Fluorescence Analysis in Ultra-violet Light," Chapman and Hall, London, 2d ed., 1935. This is Vol. VII in the series "Monographs on Applied Chemistry" edited by E.H. Tripp. It is a "setting in order and sifting the known experimental facts in connexion with the analytical use of ultra-violet light."

Kayser, H., "Handbuch der Spectroscopie," S. Hirzel, Leipzig, 1900– . The eighth volume is incomplete. Owing to the radical changes in terminology during the last few years plans have been made to publish a new and strictly up-to-date edition. [Cf. *J.Phys.Chem.*, **37**, 539–40 (1933).]

Van Nieuwenburg and Dulfer, "Short Manual of Systematic Qualitative Analysis," D.B. Centen's Uitig, Amsterdam, 1934. [See *Chemistry & Industry* **53**, 391 (1934).]

Rogers and Kerr, "Thin-section Mineralogy," McGraw-Hill Book Co., New York, 1933. A general introduction to mineral optics and description of individual minerals. Powder methods as well as thin sections are considered. "Artificial minerals" are not included.

Winchell, A.N., "Microscopic Character of Artificial Inorganic Solid Substances or Artificial Minerals," John Wiley & Sons, New York, 2d ed., 1931.

Quantitative analysis

Rüdisüle, A., "Nachweis, Bestimmung und Trennung der chemischen Elemente," Akademische Buchhandlung von Max Drechsel (Paul Haupt after Vol. V), Bern, 1913– .

This comprehensive survey of analytical methods, as originally planned, is to comprise nine volumes, of which the first six and part of the seventh have appeared. The elements are discussed separately under two main divisions: (*a*) qualitative tests, in which only the most important reactions and separations are mentioned including references to microscopic methods; (*b*) quantitative part which is subdivided into gravimetric, volumetric, electrometric, and colorimetric methods. Finally, the separations from all elements previously discussed are considered. In each volume the "Nachtrag" brings down to date the consideration of all elements previously mentioned. Because of the fact that no volume containing a Nachtrag was published after 1923 a special supplement was started in 1935 which, when complete, will help to bring the work up to date.

When searching for data concerning any element the correct procedure is to examine first the material in the volume containing the initial discussion, then the Nachtrag of each succeeding volume. Although this system is somewhat cumbersome it does help to keep the set abreast of the advances. Literature references are given as footnotes, original articles and abstracts being cited. A brief summary is given in Table 39.

TABLE 39.—SUMMARY OF RÜDISÜLE'S SURVEY OF ANALYTICAL METHODS

Volume	Published	Contents
I	1913	As, Sb, Sn, Te, Se
II	1913	Au, Pt, V, W, Ge, Mo, Ag, Hg
III	1914	Cu, Cd, Bi, Pb
IV	1916	Pd, Os, Rh, Be, Ir, Fe, Ru, Ti, Si
V	1918	Al, Ni, Co, Mn, Zn, Cr, U
VI	1923	Pt. 1: K, Na, NH_4, Ba, Sr, Ca, Mg
	1923	Pt. 2: Tl, Th, Zr, rare earths, Ra
VII	1929	Pt. 1: S
	—	Pt. 2: C
	—	Pt. 3: N
	—	Pt. 4: P
VIII	—	Halogens, O, H, noble gases
IX	—	Naturally occurring and commercial products
Suppl. I........	1936	Elements in Vol. I–IV, As-Be

BERL-LUNGE, "Chemisch-technische Untersuchungs-Methoden," Julius Springer, Berlin. 8th ed. in 5 vols., 1931–4. An English version of an earlier edition known as Lunge and Keane's "Technical Methods of Chemical Analysis," edited by C.A. Keane and P.C.L. Thorne, published by Gurney and Jackson[1] in London, is to be in six volumes of which the third was issued in 1931.

This book is especially valuable to the industrial chemist because it deals with the examination of raw materials, analyses necessary to control each stage of a process, the assay of intermediates, and valuation of final products. In most cases the discussion is linked to a particular industry so that the significance and objective of each analysis are apparent. "The plan of the book consists in treatment of the technical methods of analysis, applicable to specific industries, in separate sections; all the important inorganic and organic industries are dealt with and each section has been written by a contributor . . . practically acquainted with the subject. . . . Each section is arranged in the order (1) raw materials, (2) intermediate products, (3) methods of control, (4) final products." Of course American practice will differ from European, and organization of the work in all American plants will not be the same, but

[1] The American agent is D. Van Nostrand Co., New York.

once the general situation is known local conditions will be more readily understood.

Volume I
- Technical methods
- Qualitative analysis
- Volumetric analysis
- Electrometric analysis
- Gas analysis
- Metallography
- Optical methods
- X-ray methods
- Colloid chemistry methods
- Microchemical methods

Volume II
- Part I
  - Solid and liquid fuels
  - Water
  - Manufacture of H_2SO_3, HNO_3, H_2SO_4, HF
  - Sulfate and HCl industry
  - Soda
  - Chlorine
  - Potassium salts
- Part II
  - Electrometric methods
  - Individual elements, e.g., Ag, Au (assay) Al, As . . .

Volume III
- Clay
- Ceramic ware
- Mortar
- Glass
- Enamels
- Barium compounds
- Phosphorus acids
- Fertilizers
- Acetylene and ethylene
- Explosives

Volume IV
- Gas manufacture
- Cyanogen compounds
- Coal tar
- Fats and waxes
- Petroleum
- Inks

Volume V
- Sugar
- Alcohol
- Wine
- Acetic acid
- Rubber
- Paper
- Rayon
- Plastics
- Gelatin and glue
- Inorganic dyes
- Organic dyes
- Leather

Allen, A.H., "Commercial Organic Analysis," P. Blakiston's Son & Co., Philadelphia, 5th ed., 10 vols., 1923–33. Edited by Sadtler, Lathrop, and Mitchell. "A treatise on the properties, modes of analysis, and proximate analytical examination of the various organic chemicals and products employed in the arts, manufactures, medicine, etc., with concise methods for the detection and estimation of their impurities, adulterations, and products of decomposition."

Scott, W.W. (ed.), "Standard Methods of Chemical Analysis," D. Van Nostrand Co., New York, 4th ed., 2 vols., 2d printing,

1927. "A manual of analytical methods and general reference for the analytical chemist and for the advanced student." A new revision, edited by N. H. Furman, will be ready soon.

TABLE 40.—SUMMARY OF ALLEN'S "COMMERCIAL ORGANIC ANALYSIS"

Volume	Published	Contents (in part)
I	1923	Alcohols, wines, yeast, sugars, starch, paper, aliphatic acids
II	1924	Oils, fats, and waxes; higher fatty acids; soaps, glycerin
III	1925	Hydrocarbons, phenols, aromatic acids, phthalic acid and phthaleins, explosives
IV	1925	Essential oils, resins, rubber
V	1927	Tannins, inks, leather, natural dyes, benzene and homologues
VI	1928	Dyes, analysis of dyes
VII	1929	Alkaloids
VIII	1930	Glucosides, enzymes, cyanogen, proteins
IX	1932	Proteins, milk and milk products, meat and meat products
X	1933	Haemoglobin, proteins, vitamins, hormones, wood identification, pectins

Professor Scott has tried to compile the best technical methods of analysis. His material is divided into three main groups. Part I takes up the determination of the elements in alphabetical order; Part II covers special subjects as alloys, paint, cement, gas, explosives, water, rubber, coal, poisons; Part III contains "tables and useful data." In Part I a chapter is generally devoted to each element. A few physical properties in fine print are at the beginning of the section, then a discussion of the more important qualitative tests. Next there is a brief statement of the more important methods of determination which is followed by suggestions for the preparation and solution of samples of the common materials in which the element occurs. Typical separations are described, and the approved gravimetric and volumetric methods outlined. Frequently suggestions for determining traces of the element are included. The remarkable popularity of this book is indicated by the fact that almost 15,000 copies of the earlier editions have been printed.

Griffin, R.C., "Technical Methods of Analysis," McGraw-Hill Book Co., New York, 2d ed., 1927. A representative selection of the analytical methods used in the laboratory of Arthur D. Little, Inc. The book includes material on inorganic and organic analysis, metals, fuels, paints, oils, wood and wood products, textiles, food, and water. Among the topics omitted are drugs, alkaloids, rare elements, gas analysis, rock analysis, and glass.

Hillebrand and Lundell, "Applied Inorganic Analysis," John Wiley & Sons, New York, 1929. Part I takes up a general discussion of quantitative operations. Part II deals with the individual elements, setting forth the best methods for their determination as revealed by experience. Parts III and IV are practically a revision of the well-known U.S. Geological Survey Bulletin 700, "The Analysis of Silicate and Carbonate Rocks," by Hillebrand. Part V is concerned with the analysis of soda-lime glass and materials high in alumina such as bauxite. From the standpoint of the mature chemist interested in high-grade work this book is one of the best available.

Treadwell and Hall, "Analytical Chemistry," Vol. II, Quantitative Analysis, John Wiley & Sons, New York, 8th ed., 1935.

Mitchell and Ward, "Modern Methods in Quantitative Chemical Analysis," Longmans, Green & Co., New York, 1932.

Theory

Rieman and Neuss, "Quantitative Analysis," McGraw-Hill Book Co., New York, 1937. A theoretical approach to the subject.

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Textbooks

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Fales, H.A., "Inorganic Quantitative Analysis," The Century Co., New York, 1925.

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MELLON, M.G., "Methods of Quantitative Chemical Analysis," The Macmillan Co., New York, 1937.

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SMITH, G.McP., "Quantitative Chemical Analysis," The Macmillan Co., New York, 3d ed., 1933.

TALBOT, H.P., "An Introductory Course of Quantitative Chemical Analysis," The Macmillan Co., New York, 7th ed., by Hamilton and Simpson, 1931.

WILLARD and FURMAN, "Elementary Quantitative Analysis. Theory and Practice," D. Van Nostrand Co., New York, 2d ed., 1935.

Volumetric methods, general

BECKURTS, H., "Die Methoden der Massanalyse," Fr. Vieweg und Sohn, Braunschweig, 2d ed., 1931, by R. Berg and R.R. Dietzel. The first edition of this book, published in sections during the period 1910–13, was issued to take the place of the eighth edition of Fr. Mohr's "Lehrbuch der chemisch-analytischen Titriermethode," the seventh edition of which had been prepared by Classen and released in 1896. Although Beckurts' work includes all of the best volumetric methods of the time it is outstanding in one other respect, viz., that the literature references frequently mention the first articles advocating a particular procedure. For example, the original papers describing the use of permanganate as a standardized oxidant are listed on p. 485. Thus anyone interested in the history of a method will find Beckurts very valuable. Incidentally there is a chronological table of the advances in volumetric analysis on pp. 1031–45. It covers the period 1756 to 1903. Though the second edition is complete and up to date in many respects the compilers have deleted much of the data historically important.

JANDER and JAHR, "Massanalyse . . . ," Walter de Gruyter Co., Leipzig, 1935. The theory and technique of classical and electrochemical volumetric methods.

KOLTHOFF, I.M., "Die Massanalyse," Julius Springer, Berlin, Part I, Theoretical, 1927; Part II, Practical, 1928. A translation of this book was prepared by N.H. Furman and published by John Wiley & Sons in 1929.

SUTTON, F., "Systematic Handbook of Volumetric Analysis," P. Blakiston's Son & Co., Philadelphia, 12th ed., 1935, by A.D. Mitchell. This has been the standard English text for a number of years.

JAMIESON, G.S., "Volumetric Iodate Methods," Chemical Catalog Co., New York, 1926.

Electrometric methods

BRITTON, H.T.S., "Conductometric Analysis," D. Van Nostrand Co., New York, 1934. Covers principles, technique, and applications of the subject.

KOLTHOFF and FURMAN, "Potentiometric Titrations," John Wiley & Sons, New York, 2d ed., 1932. The book is divided into three parts: I, Fundamental Principles; II, Technique; III, Practical Applications.

KOLTHOFF, I.M., "Colorimetric and Potentiometric Determination of pH," John Wiley & Sons, New York, 1931. An introduction to the work in bacteriology and biochemistry. Colorimetric, potentiometric, and conductometric methods are discussed.

MICHAELIS, L., "Oxidation-reduction Potentials," J.B. Lippincott, Philadelphia, 1930.

MÜLLER, ERICH, "Die elektrometrische Massanalyse," T. Steinkopff, Dresden, 5th ed., 1932. The appearance of five editions in 11 years is some indication of the rate of advance in potentiometric methods. Approximately 400 references are given in the bibliography on pp. 269–76.

Acidimetry

BRITTON, H.T.S., "Hydrogen Ions," D. Van Nostrand Co., New York, 1929. "Their determination and importance in

pure and industrial chemistry." Contains a good discussion of the pH at which various hydroxides precipitate, also the application of pH measurements in various industrial operations.

CLARK, W.M., "The Determination of Hydrogen Ions," The Williams & Wilkins Co., Baltimore, 3d ed., 1928. "An elementary treatise on electrode, indicator and supplementary methods with an indexed bibliography on applications."

KOLTHOFF and FISCHGOLD, "Säure-Basen-Indikatoren, ihr Anwendung bei der colorimetrischen Bestimmung der Wasserstoffionen-konzentration," Julius Springer, Berlin, 1933.

PRIDEAUX, E.B.R., "Theory and Use of Indicators," Constable & Co., London, 1917. "An account of the chemical equilibria of acids, alkalis and indicators in aqueous solution, with applications."

Special Processes

BÖTTGER, W. (ed.), "Physikalische Methoden der analytischen Chemie," Akademische Verlagsgesellschaft, Leipzig. In two parts: I, 1933; II, 1936. Sections by qualified authors on spectroscopy; radiometric, conductometric, potentiometric, polarographic, and thermochemical analysis; photoelectric methods and analysis by vaporization.

CLASSEN and DANNEEL, "Quantitative Analyse durch Electrolyse," Julius Springer, Berlin, 7th ed., 1927.

EMICH, F., "Microchemical Laboratory Manual," John Wiley & Sons, New York, 1932. This is the translation by F. Schneider, It contains a section on spot analysis by Feigl.

FISCHER, A., "Elektroanalytische Schnellmethoden," F. Enke, Stuttgart, 2d ed., revised by A. Schleicher, 1926.

GERLACH and SCHWEITZER, "Foundations and Methods of Chemical Analysis by the Emission Spectrum," Adam Hilger, Ltd., London, 1932. This is an authorized translation from the German version.

PREGL, F., "Die quantitative organische Mikroanalyse," Julius Springer, Berlin, 3d ed., 1930. There is an English translation of this edition by E.B. Daw. It was published by J. and A. Churchill of London in 1937.

SNELL and SNELL, "Colorimetric Methods of Analysis," D. Van Nostrand Co., New York, 2 vols., I, Inorganic, 1936; II, Organic and Biological, 1937. This is a summary of the various methods involving colorimetry.

YOE, J.H., "Photometric Chemical Analysis (Colorimetry and Nephelometry)," John Wiley & Sons, New York. In two parts: Vol. I, 1928; Vol. II, 1929.

"Official" methods

Frequently the analyst is called upon to test materials for the purpose of determining whether they meet certain specifications either governmental or as agreed upon in a business transaction. In all such cases he should use methods having legal status. A few of the more important sources of information regarding acceptable procedures are given in the following list.

COMMITTEE OF REVISION, "Pharmacopoeia of the United States of America," published by the Board of Trustees of the United States Pharmacopoeial Convention, P. Blackiston's Son & Co., Philadelphia, being designated as agents. A revised edition of this book is issued every 10 years; the eleventh has been official since 1936.

This book is intended to provide a standard for drugs and medicines of known origin. It contains definitions, receipts, properties, assay, and dosage for all "official" materials used in pharmaceutical work. In addition there are directions for a number of "General Tests," e.g., Arsenic Test, Heavy Metals Test, Melting Points, Boiling Points. Very few therapeutic data are given. Whenever the analyst encounters a problem involving pharmacopoeial materials he should use the prescribed method and obtain his directions from an "official" copy, each of which has a special, numbered label on the back of the title page.[1]

COMMITTEE ON EDITING METHODS OF ANALYSIS, "Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists," Washington, Association of Official Agricultural Chemists, 4th ed., 1935. The methods in this book

[1] C.J. Carr has published a good description of the U.S.P. in *J. Chem. Education* **8**, 515–19 (1931). He discusses the history, data of particular value to the technician, etc.

"are formulated by responsible Federal and State officials acting together . . . [the methods] are accepted as authoritative in matters at issue before the courts, both Federal and State." They cover such products as:

Fertilizers	Canned vegetables
Feeding stuffs	Meats
Preservatives	Dairy products
Coloring matters in foods	Vinegars
Metals in foods	Flavoring extracts
Sugars	Wines and liquors

Changes in methods authorized by the Association, when made between revisions of the book, are published in the *Journal of the Association of Official Agricultural Chemists.*

AMERICAN PUBLIC HEALTH ASSOCIATION, "Standard Methods for the Examination of Water and Sewage," American Public Health Association, New York, H.E. Jordan, editor, 1936. Physical, chemical, and bacteriological examinations are considered.

AMERICAN SOCIETY FOR TESTING MATERIALS, "Book of Standards" "Book of Tentative Standards," American Society for Testing Materials, Philadelphia. The "Book of Standards" was published biennially down to 1918, thereafter triennially. The latest issue appeared in 1936. Usually a "Book of Standards Supplement" has been issued each intervening year. The "Book of Tentative Standards" is published annually. "Standards" are obtainable separately as pamphlets at about twenty-five cents a copy. An especially valuable booklet is the free "Index to Standards," issued annually. It "gives complete references to all publications where standards or tentative standards appear in their latest form." The society has sponsored a number of other publications, a list of which may be obtained upon request.

The A.S.T.M. was started at Philadelphia in 1898 by the American members of the International Association for Testing Materials, as the American section of that organization. In 1902 the section was incorporated as an independent association under the name "American Society for Testing Materials." The objective of the society was, and still is "the promotion of knowledge of the materials of engineering and the standardization

of specifications and methods of testing." Committees are appointed for the investigation of various materials and methods. Recommendations thus arising are usually published as "tentative Standards" for one or two years. If favorably received they are adopted as "Standards" which may be modified, if subsequent experience demands.

Whenever goods are bought or sold a very important feature of the transaction is the nature of the material changing hands. Is it what the purchaser requires? If not is he at fault as a result of vagueness in stating his needs, or is the seller unfamiliar with his wares? In order to avoid misunderstandings and the possibility of expensive litigation the A.S.T.M., using committees representing both manufacturers and consumers, has attempted to study a variety of products and set up fair specifications for a contract covering their purchase. If one desires 100 tons of zinc spelter, for example, the standards B 6-33 and B 69-29[1] adequately describe the commercial grades of that metal, outline the procedure for sampling, the chemical analysis of a shipment, and indicate the steps to be taken if the purchaser claims that the contract has not been fulfilled.

The books of Standards and Tentative Standards contain specifications, methods of testing, and recommended practices for iron, steel, the non-ferrous metals and alloys, cement, etc. (see Table 41). The 1936 "Book of Standards" consists of 513 standards published in two divisions. Part I contains 181 standards relating chiefly to ferrous and non-ferrous metals; Part II covers 335 criteria for non-metallic materials. The "1937 Supplement" contains standards adopted or revised since the publication of the "Book of Standards." The latest "Book of Tentative Standards" (1936) contains 264 tentative specifications. A "guide to the use of" these books will be found on the page facing the table of contents in each volume.

U.S. Bureau of Standards, "Encyclopedia Series," Superintendent of Documents, Government Printing Office, Washington, 1927– . This series contains volumes giving nationally recognized standards and specifications. The first volume (published in 1927) is concerned with the wood-using industries; the second deals with the non-metallic minerals (Miscellaneous Publication 110 issued in 1930); the third covers metals and metal

[1] See the 1936 "Book of Standards," Part I, pp. 705–16.

products both ferrous and non-ferrous (Miscellaneous Publication 120 issued in 1933).

TABLE 41.—A PARTIAL LIST OF A.S.T.M. STANDARDS

	A. Ferrous Metals
A 33-24	Methods of Chemical Analysis of Plain Carbon Steel. Replaced by E 30-36 T
A 55-24	Methods of Chemical Analysis of Alloy Steels. Replaced by E 30-36 T
A 64-27	Methods of Sampling and Chemical Analysis of Pig and Cast Iron. Replaced by E 30-36 T
A 103-36 T	Methods of Sampling Ferro-alloys
A 104-36 T	Methods of Chemical Analysis of Ferro-alloys
	B. Non-ferrous Metals
B 5-27	Specifications for Electrolytic Copper
B 23-26	Specifications for White Metal Bearing Alloys (Babbitt Metal)
	C. Cement, Lime . . .
C 9-30	Specifications for Portland Cement
C 18-35	Methods of Chemical Analysis of Refractory Materials
C 25-29	Methods of Chemical Analysis of Limestone . . .
C 77-32	Methods of Sampling and Testing Portland Cement
	D. Miscellaneous Materials
D 21-16	Method of Sampling Coal
D 86-35	Method of Test for Distillation of Gasoline . . .
D 271-33	Methods of Laboratory Sampling and Analysis of Coal and Coke
	E. Metallography, General Testing Methods
E 2-36	Rules Governing the Preparation of Micrographs of Metals and Alloys . . .
E 11-26	Specifications for Sieves for Testing Purposes

Idem, "Standards Yearbook," Superintendent of Documents, Government Printing Office, Washington, 1927–33(?). Published annually. Contains data on standardization activities both governmental and private, American and foreign.

Special subjects

Brass

PRICE and MEADE, "Technical Analysis of Brass . . . ," John Wiley & Sons, New York, 2d ed., 1917.

Fats and oils

LEWKOWITSCH (Warburton), "Chemical Technology and Analysis of Oils, Fats, and Waxes," The Macmillan Co., New York, 6th ed., 3 vols., 1923.

Ferrous alloys

Blair, A.A., "Chemical Analysis of Iron," J.B. Lippincott Co., Philadelphia, 8th ed., 1918.

Johnson, C.M., "Rapid Methods for the Chemical Analysis of Special Steels . . . ," John Wiley & Sons, New York, 4th ed., 1930.

Lord and Demorest, "Metallurgical Analysis," McGraw-Hill Book Co., New York, 5th ed., 1924.

Lundell, Hoffman, and Bright, "Chemical Analysis of Iron and Steel," John Wiley & Sons, New York, 1932.

Naish and Clennell, "Select Methods of Metallurgical Analysis," John Wiley & Sons, New York, 1929. The methods are briefly described, but good bibliographies are appended.

Sisco, F.T., "Technical Analysis of Steel and Steel Works Materials," McGraw-Hill Book Co., New York, 1923.

Food

Woodman, A.G., "Food Analysis," McGraw-Hill Book Co., New York, 3d ed., 1931.

Fuel

American Gas Association, "Gas Chemists' Handbook," Chemical Publishing Co., Easton, Pa., 3d ed., 1929.

Dennis and Nichols, "Gas Analysis," The Macmillan Co., New York, 2d ed., 1929.

Lunge, G., "Technical Gas Analysis," Gurney and Jackson, London, revised by H.R. Ambler, 1934.

Parr, S. W., "Analysis of Fuel, Gas, Water and Lubricants," McGraw-Hill Book Co., New York, 4th ed., 1932.

U.S. Steel Corporation, "Methods of the Chemists of . . . for Sampling and Analysis of Coal, Coke and By-products," The Carnegie Steel Co., Pittsburgh, Pa., 2d ed., 1923.

White, A.H. "Technical Gas and Fuel Analysis." McGraw-Hill Book Co., New York, 2d ed., revised, 1920.

Ores

Low, A.H., "Technical Methods of Ore Analysis," John Wiley & Sons, New York, 10th ed., 1927, reissued in 1935.

Petroleum

American Petroleum Institute, "Standard Methods for Testing Petroleum and Its Products." (Cf. A.S.T.M. Standards.)

Reagents

Rosin, J., "Reagent Chemicals and Standards," D. Van Nostrand Co., New York, 1937. The author has assembled the latest information concerning reliable methods and tests.

Rocks

Washington, H.S., "Chemical Analysis of Rocks," John Wiley & Sons, New York, 1930. Excellent. (Cf. Hillebrand and Lundell, p. 174.)

Van Tongeren, W., "Gravimetric Analysis," H.K. Lewis & Co., London, 1937. A laboratory manual dealing especially with the analysis of natural minerals and rocks.

Sugar

Browne, C.A., "Handbook of Sugar Analysis," John Wiley & Sons, New York, 1st ed., 1912.

Spencer, G.L., "Handbook for Cane-sugar Manufacturers and Their Chemists," John Wiley & Sons, New York, 7th ed., revised by G.P. Meade, 1929.

Water

Mason and Buswell, "Examination of Water," John Wiley & Sons, New York, 6th ed., revised 1931. Cf. American Public Health Association, p. 179.

PHYSICAL CHEMISTRY AND PHYSICAL CONSTANTS

> *"The fact that the same statement occurs in a large number of books should never be considered as proof of its accuracy unless . . . the different authors obtained the results independently."* MURRAY

Physical chemistry as a main branch of the science is, in one sense, the youngest of the four divisions. It was established largely through the efforts of Wilhelm Ostwald (1853–1932) whose greatest contribution, perhaps, was the training of research students.[1] Among those coming under his influence was Walther Nernst (1864–), frequently acclaimed the world's greatest physical chemist. He served as Privatdocent in Leipzig from 1889 until called to Göttingen two years later whence he went to Berlin in 1905. Under the stimulus of these two men physical chemistry advanced so rapidly that it soon reached the stage of disintegration into electrochemistry, colloid chemistry, etc. Today one concentrating in the field is known, for example, as a colloid chemist, not as a physical chemist specializing in colloids.[2]

In view of this situation the present chapter should be separated into three or more to insure adequate treatment of the various parts of the subject. When the time has arrived, however, for a student to restrict his activities to one subdivision it is believed that he should possess the bibliographical skill necessary to acquaint himself with the pertinent literature. Hence the discussion here will be confined to the broader aspects of physical chemistry and the books devoted to compilations of physical data with only brief mention of the more important treatises on colloids, electrochemistry, and the other branches.

[1] Many of our eminent American physical chemists studied in his laboratory at Leipzig. Cf. Bancroft, *J.Chem.Education* **10**, 539, 609 (1933).

[2] For an interesting historical summary of physical chemistry see the article "An Introduction to the Study of Physical Chemistry" by Sir William Ramsay in the first edition of Findlay's "Phase Rule" or in Young's "Stoichiometry," both published by Longmans, Green & Co., New York.

Use

The general procedure for locating subject matter in physical chemistry is fundamentally the same as that outlined for the inorganic and analytical divisions. If the searcher is unacquainted with the nature and relationships of a topic the first source to consult is not a highly specialized article dealing with one phase of the problem. A general treatise or textbook is more useful because it will furnish the necessary background and perspective without which an intelligent search and interpretation of results is impossible. Furthermore, the best sources of information may be overlooked, and articles containing important data ignored, because their significance or relationship is not appreciated. In this borderline field one must also remember that books normally classed in the other subject may be very useful, since, in many cases, the name "chemical physics" is just as appropriate as "physical chemistry."

PHYSICAL CHEMISTRY BIBLIOGRAPHY

An attempt has been made in the following bibliography to list general surveys of the whole of physical chemistry, general surveys of some of the subdivisions, and treatises on a few more restricted topics. Although none has been listed, books more properly classed as physics should also be taken into consideration.

Serial publications

(American)[1] *Electrochemical Society, Transactions.* The object of this society "is the advancement of the theory and practice of Electrochemistry, Electrometallurgy, Electrothermics, Electrotechnics and allied subjects." Two meetings are held annually at which papers are read and discussed. Confidential copies of the papers are issued to members before each meeting to facilitate discussion. Subsequently the articles and comments are published in book form. Collective indexes are available for Vols. 1–20, 21–40, 41–60. The society was started in 1902.

Annales de chimie. Established in 1789 by Morveau, Lavoisier, Berthollet, Fourcroy, *et al.* It is the oldest chemical journal still appearing. From 1816 to 1914 the name was *Annales de*

[1] The word "American" was dropped in 1931.

chimie et de physique. The first series, 1789–1815, contains 96 volumes plus 3 index volumes; the second series, 1816–40, has 75 volumes plus 3 of index; the third series, 1841–63, contains 69 volumes plus 2 for the index. Subsequent series run 30 volumes each and cover a 10-year period. The papers in this journal are generally long, consider an extended problem, and correlate the progress reports previously published in the *Comptes rendus.*

"Colloid Symposium Monographs," Chemical Catalog Co., New York, 1923– . An annual publication edited by H.B. Weiser and consisting of papers read at the symposium of the year concerned.

Faraday Society, Transactions. This journal was started in 1905 "to promote the study of electrochemistry, electrometallurgy, physical chemistry, metallography and kindred subjects." There is one volume each year, containing about 800 pages. Individual issues are published every 4 to 6 weeks, being released before the papers are read at a meeting. This plan tends to promote more adequate discussion. Another excellent activity of the society is to sponsor symposia or "general discussions" dealing with timely subjects. A few of physico-chemical interest are:

Osmotic Pressure	**3**, 12–37 (1907), **13**, 119–189 (1917–18)
Present Position of Theory of Ionization	**15**, Pt. I, 3–178 (1919–20)
Physical and Physico-chemical Problems Relating to Textile Fibers	**20**, 223–324 (1924–5)
Physical Chemistry of Igneous Rock Formation	**20**, 414–501 (1924–5)
Physical Phenomena at Interfaces	**22**, 434–500 (1926)
Theory of Strong Electrolytes	**23**, 334–541 (1927)
Crystal Structure and Chemical Constitution	**25**, 253–421 (1929)
Photochemical Processes	**27**, 359–573 (1931)
Colloid Aspects of Textile Materials	**29**, 3–368 (1933)
Free Radicals	**30**, 3–248 (1934)
Dipole Moment	**30**, 679–903 (1934)
Colloidal Electrolytes	**31**, 4–422 (1935)
Structure and Molecular Forces	**33**, 1–159 (1937)

Fortschritte der Chemie, Physik und physikalischen Chemie. This is essentially a monograph series. It was started in 1909 as the successor to the Physikalisch-Chemisches Zentralblatt first

published in 1905. Issues appear monthly. There are collective indexes for Vols. 1 to 5 (1909–13) and Vols. 6 to 16 (1914–23).

Journal de chimie physique. Established in 1903 by Ph.A. Guye, it is now edited by a committee of Belgian, French, and Swiss chemists. During the first four or five years abstracts of physico-chemical papers were published. The field covered is electrochemistry, thermochemistry, radiochemistry, chemical mechanics, and stoichiometry. There is one volume yearly.

Journal of Physical Chemistry. Founded in 1896 as a private venture by Wilder D. Bancroft, this journal is now sponsored by the American Chemical Society, Faraday Society, and Chemical Society (London).[1] Each year there is one volume of twelve issues containing short articles. The book reviews are especially good.

Kolloid(chemisches) Beihefte. Volume I was issued in October, 1909, by Wolfgang Ostwald as a supplement to the Kolloid Zeitschrift (*q.v.*). The name was changed to "Kolloid Beihefte" in September, 1931. The Beihefte contain monographs on pure and applied colloid chemistry. These articles are complete accounts of extensive investigations short reports of which have appeared from time to time in the Kolloid Zeitschrift.

Kolloidforschung in Enzeldarstellungen. A series of monographs started in 1925 and published by the Akademische Verlagsgesellschaft under the editorship of R. Zsigmondy.[2] A few of the titles are:

Volume	Date	Title and author
V	1926	Polarizing Microscope, Ambronn and Frey
VI	1927	Catalysis with Colloidal Metals, W. Hückel
VIII	1929	Colloidal Silver, J. Voigt

Kolloid Zeitschrift. Started by the publishers T. Steinkopff and J. Springer in 1906 as the organ for the entire field of pure and applied colloid chemistry. In 1907 Wolfgang Ostwald became editor. The journal appears monthly containing short

[1] For details of this change see *Ind.Eng.Chem., News Ed.*, **10**, 229 (1932).
[2] Now under the direction of H. Freundlich.

papers, good abstracts, and, occasionally, good bibliographies. There is a collective index to Vols. 1 to 50 (1906–30). About two volumes are issued each year.

Zeitschrift für Elektrochemie und angewandte physikalische Chemie.[1] Established in 1894 for the publication of papers on electrochemistry; today they are chiefly general and physical in nature. Good reviews are frequently published. There is one volume per year and a cumulative index to the first ten volumes.

Zeitschrift für physikalische Chemie. Part A. Chemische Thermodynamik, Kinetik, Electrochemie, Eigenschaftslehre. Part B. Chemie der Elementarprozesse, Aufbau der Materie. This journal was started by Wilhelm Ostwald and J.H. van't Hoff in 1887 as the Zeitschrift für physikalische Chemie, Stöchiometrie und Verwandschaftslehre. There was one volume in each of the first two years, then two per year until 1893, three until 1898, and four to five down to the World War period. The division into Parts A and B came in 1928. The former continued with five to six volumes per year, and the latter required an equal number. Cumulative indexes have been issued for the earlier volumes.

"Hand- und Jahrbuch der chemischen Physik." Published by the Akademische Verlagsgesellschaft under the editorial guidance of Eucken and Wolf. "Das Handbuch soll eine umfassende Behandlung der Strukturfragen der Materie zum Gegenstand haben." The prospectus lists 12 volumes by well-known scientists (see Goldschmidt, p. 194).

Reference books

OSTWALD, WILHELM, "Lehrbuch der allgemeinen Chemie," Akademische Verlagsgesellschaft,[2] Leipzig, 2d ed., 2 vols., 1910. Vol. I, Stoichiometry; Vol. II, Part 1, Chemical Energy; Parts 2 and 3, Affinity. Although not extensively used this has been one of the foremost books in the field.

OSTWALD-DRUCKER (Walden), "Handbuch der allgemeinen Chemie," Akademische Verlagsgesellschaft, Leipzig, 1918– . A series of monographs on various phases of physical chemistry.

[1] The title has varied slightly.

[2] Originally published by Engelmann.

This series was founded by Ostwald but more recently has been under the editorial guidance of Paul Walden and Carl Drucker. Each treatise is intended to be a complete survey of all essential literature on the subject. The issues to date are given in Table 42.

TABLE 42.—SUMMARY OF THE "HANDBUCH DER ALLGEMEINEN CHEMIE"

Volume	Date	Author and title
I	1919	Ostwald: Chemical Literature and the Organization of Knowledge
II	1918	Ramsay and Rudorf: The Noble Gases
III	1919	Kuenen: The Properties of Gases. (Kinetic Theory, Equation of State)
IV	1924	Walden: The Conductivity of Solutions. (3 parts in 2 volumes)
V	1928	Kremann: Mechanical Properties of Liquids
VI	1928	Ephraim: Principles of Valence and Bonds
VII	1928	Swietoslawski: Thermochemistry
VIII, 1	1930	Kremann and Müller: Electromotive Force
2	1930	*Idem:* Electrolysis and Polarization
IX	1937	Fricke and Huttig: Hydroxides and Oxide Hydrates

JELLINEK, KARL, "Lehrbuch der physikalischen Chemie," F. Enke, Stuttgart, 1928– . A comprehensive treatise in five volumes a brief survey of which will be found in Table 43.

TABLE 43.—SUMMARY OF JELLINEK'S "LEHRBUCH"

Volume	Date	Contents
I	1928	Fundamental Principles. Pure substances in the liquid state (2d ed.)
II	1928	Pure Substances in the Solid State. Dilute solutions (2d ed.)
III	1930	Statics of Chemical Reactions in Dilute Solutions
IV	1931	Statics. Reactions. Chemical Kinetics
V	1933–	Statics. Dilute Solutions (concluded). Concentrated Solutions. The Phase Rule. (Pt. 14 of this volume was issued in 1935.)

TAYLOR, H.S. (ed.), "Treatise on Physical Chemistry," D. Van Nostrand Co., New York, 2d ed., 1931. "A cooperative effort by a group of physical chemists." Very popular.

Lewis, W.C.Mc., "A System of Physical Chemistry," Longmans, Green & Co., New York; Vol. I, Kinetic Theory (2d ed., 1918); Vol. II, Thermodynamics (4th ed., 1925); Vol. III, Quantum Theory (3d ed., 1925).

Nernst, W., "Theoretische Chemie," F. Enke, Stuttgart, 11th to 15th ed., 1926.

Eucken, A., "Fundamentals of Physical Chemistry for Students of Chemistry and Related Sciences," McGraw-Hill Book Co., New York, 1925, trans. by Jette and La Mer from the 2d German ed.

Walker, J., "Introduction to Physical Chemistry," The Macmillan Co., New York, 9th ed., 1922. A standard text for many years.

Friend, J.N., "Physical Chemistry," J.B. Lippincott Co., Philadelphia; Vol. I, 1934, General Properties of Elements and Compounds; Vol. II, 1935, Chemical Reactivity.

Eggert, J., "Physical Chemistry," D. Van Nostrand Co., New York, trans. from the German by S.J. Gregg, 1936.

Textbooks

Findlay, A., "Introduction to Physical Chemistry," Longmans, Green & Co., New York, 1933.

Getman-Daniels, "Outlines of Theoretical Chemistry," John Wiley & Sons, New York, 6th ed., 1937. Considered one of the best texts from the standpoint of fundamentals for the beginner.

MacDougall, F.H., "Physical Chemistry," The Macmillan Co., New York, 1936.

Millard, E.B., "Physical Chemistry for Colleges," McGraw-Hill Book Co., New York, 4th ed., 1936.

Noyes and Sherrill, "Chemical Principles," The Macmillan Co., New York, 1922. This book is for advanced students.

Rodebush and Rodebush, "An Introductory Course in Physical Chemistry," D. Van Nostrand Co., New York, 1933.

Taylor and Taylor, "Elementary Physical Chemistry," D. Van Nostrand Co., New York, 1935.

WEBB, T.J., "Elementary Principles in Physical Chemistry," D. Appleton-Century Co., New York, 1936. Good for the development of formulas.

Laboratory guides

OSTWALD-LUTHER, "Hand- und Hilfsbuch zur Ausführung physikochemischer Messungen," Akademische Verlagsgesellschaft, Leipzig, 5th ed., 1931. C. Drucker, ed. Among the best in its field.

REILLY and RAE, "Physico-chemical Methods," D. Van Nostrand Co., New York, 2d ed., 1933.

DANIELS, MATHEWS and WILLIAMS, "Experimental Physical Chemistry," McGraw-Hill Book Co., New York, 2d ed., 1935.

FAJANS and WÜST, "Textbook of Practical Physical Chemistry," E.P. Dutton and Co., New York, 1930. English translation by Topley. The second German edition was published by the Akademische Verlagsgesellschaft in 1935.

FINDLAY, A., "Practical Physical Chemistry," Longmans, Green & Co., New York, 6th ed., 1936.

Colloids

ADAM, N.K., "Physics and Chemistry of Surfaces," Oxford University Press, London, 1930.

ALEXANDER, J. (ed.), "Colloid Chemistry—Theoretical and Applied," Chemical Catalog Co., New York, 1926–32.

Volume	Date	Title
I	1926	Theory and Methods
II	1928	Biology and Medicine
III	1931	Technicological Applications
IV	1932	Technical Applications

BANCROFT, W.D., "Applied Colloid Chemistry—General Theory," McGraw-Hill Book Co., New York, 3d ed., 1932.

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II	1933–	Aqueous Electrolysis in the Chemical Industry
III	1934–	Technical Electrolysis of Fused Masses
IV	—	The Electric Furnace
V	—	Electrochemical Gas Reactions, Electro-osmosis and Cataphoresis

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PHYSICAL CONSTANTS

The direction and extent of a quest for physical constants depend on the data needed and the precision with which they

must be known. No book will answer every question; neither will all figures be equally near to the true value. Disregarding, for the moment, the problem of where to look, one may well ask what criteria can be used for selecting the most accurate statement from among those published. Some of the important factors are: reputation of the investigator, when the work was done, soundness of the method, integrity of the calculations, deviation from results by other methods, probable purity of the samples used, and accuracy reasonably attainable in good work.[1] Although other factors may appear in various problems the essential point is that in a high-grade investigation no data should be accepted without question. Whenever quoted figures are encountered, as in tables of physical properties, the references may well be used as guides to the original work if for no other purpose than to guard against interchanged digits or a shifted decimal point even when only approximate values are desired. Incidentally, it is always a good practice to consult any list of errors applicable to the book used and experimentally to verify doubtful data whenever the work involved demands this assurance. Of course that critical judgment born of experience will eliminate much labor, but until the beginner has acquired the essential background it is best to err on the safe side of extra caution rather than to take a precarious position through inadequate checking.

Frequently two questions are raised: What fraction of the published data is unreliable? and How much in error are the figures normally encountered? Neither question can be answered unequivocally. Occasionally one hears an investigator say that all data in the literature on a certain subject are wrong. This may be true because recent improvements in technique or

[1] It has been stated that, with modern equipment, temperature measurements between 500 and 1000° are readily attainable within 0.1°; from 1000 to 1500°, within 1°; from 1500 to 2000°, within 10 to 15°; from 2000 to 2500° within 25 to 50°. Hence, if samples are adequately purified and protected, melting points should be known within the limits indicated. Whether a "best" value is required in any particular instance depends, of course, upon the work contemplated. If one wishes to melt zinc for brass the value *ca.* 420° is entirely satisfactory, but when used as a "fixed point" for checking a thermocouple the value 419.4_4° might be needed. Cf. U.S. Bureau of Standards Circ. 66, "Standard Samples for Thermometric Fixed Points."

measuring devices warrant the statement. Extension of the criticism to all figures is not justified, of course, but a sufficient number is wrong to cast suspicion on all and make a careful scrutiny necessary.

The extent of deviation is equally variable. Many data are precise, many are sufficiently accurate for all ordinary work, but too often one finds absurd statements which are mere traps for the unwary. These errors, of course, are typographical and obvious to one familiar with the subject. When present in original articles they form an additional menace, however, because they may get into the handbooks. Once there, it is not easy to eliminate them.

As to sources of information, they may be classed as original and secondary. The former embrace journal reports, and the latter may be one or two steps removed from them, i.e., copied directly from the journal or from an abstract of the article. Original sources have been discussed on pp. 186–9. Secondary sources can be divided into two groups: the large, encyclopedic compilations and the less pretentious handbooks, both general and specialized. There is no definite order in which they should be examined because of the variation in problems and in usefulness of the books in any particular case. A general acquaintance with all good compilations plus an intimate knowledge of a few is probably the best preparation for an average search.

Extensive compilations

Landolt-Börnstein, "Physikalisch-Chemische Tabellen," Julius Springer, Berlin, 5th ed., by Roth (chemistry) and Scheel (physics), 2 vols. paged continuously, 1923; 1st suppl., 1 vol., 1927; 2d suppl., 2 vols. 1931; 3d suppl. 3 vols. 1935–6. The first edition of this book was published in 1883 (1 vol., 249 pp.). Subsequent issues appeared at approximately 10-year intervals to establish the enviable reputation of being "until recently the compilation of most importance for chemists the world over."[1] The first volume of the fifth edition covers the fundamental chemical constants and the properties of inorganic and organic compounds. The second is devoted to the important constants of atomic physics including, especially, optical, electrical, and

[1] Crane and Patterson, p. 23.

thermal data. The supplements are similarly divided. Some of the main sections are:

Volume I

Atomic weights and radioactivity	Diffusion
Terrestrial constants	Critical data
Weight and pressure corrections	Specific gravity, melting and boiling points
Elasticity, hardness	Minerals
Compressibility	Alloys (phase diagrams)
Viscosity	Chemical equivalence
Capillarity	

Volume II

Atomic physics	Cubical expansion
Optics	Specific heat
Electricity, electrochemistry	Thermochemistry

Practically all data are given in the form of tables or graphs, each prepared by an authority in the field, e.g., atomic weights by Hönigschmid. The key to these tables is the subject index in Vol. III of the third supplement. It covers all four parts. There is also a special, alphabetical list of forty common substances with an index to the properties of each, among them being ether, alcohol, aluminum, ammonia, benzol, and water. A table of contents will be found in each volume. This is divided into main topics and subtopics. For each of the latter there is along the left margin the table number and along the right margin the page number. Thus every page carries a double identification. Page numbers, not table numbers, are given in the index. Whenever a table occupies more than one page each succeeding page bears the table number and a letter of the alphabet; thus 15b means p. 2 of Table 15, while 15bb is p. 27 of the same table.[1] The arrangement of each table is obvious from inspection.

References are given in two ways: The complete citation will accompany a value, or only the name of the investigator may appear. In the latter case the location of the bibliography is stated at the top of the table.

The most important characteristic of this work is the arrangement of the data for the convenience of the user.

"Tables annuelles de constantes et données numeriques de chimie, de physique, de biologie et de technologie," American

[1] "j" is not used.

publisher, McGraw-Hill Book Co., New York; Ch. Marie, editor-in-chief. Published under the auspices of the International Union of Pure and Applied Chemistry by the International Committee appointed by the Seventh Congress of Applied Chemistry (London, 1909). The purpose of this work[1] is "to assemble all numerical data of chemistry, physics, biology and engineering (appearing in about 500 periodicals). . . . No critical selection of the data has been made but they have been arranged and classified by competent men handling material in their own fields." The project was started in 1910 with the idea of including in one volume, to be issued as soon as possible, the data published during each year. The World War seriously delayed the appearance of several volumes, but an earnest effort is being made to get the series back to the original schedule (see Table 44).

TABLE 44.—SURVEY OF "TABLES ANNUELLES"

Volume	Period covered	Published
I	1910	1912
II	1911	1913
III	1912	1914
IV, 1	1913–16	1921
2	1913–16	1922
V, 1	1917–22	1925
2	1917–22	1926
VI, 1	1923–24	1927
2	1923–24	1928
VII, 1	1925–26	1930
2	1925–26	1930
VIII, 1	1927–28	1931
2	1927–28	1932
IX	1929	1931
X, 1	1930	1934
2	1930	1935
Index	1910–22	1930
Index	1923–30	
Index	1929	1932

When this series is being used, several aids are available. Near the front of each volume there is an "Index of Chapters."

[1] Cf. *Nature* **128**, 662–3 (1931).

It occupies one page and lists the main subdivisions in the book. This summary is followed by a "Table of Contents" which, under each section heading, gives its content and any important cross references. Many sections begin with an index. While, in general, all volumes cover the same ground, recently new divisions have been added, and in some cases a section is omitted in alternate years. Starting with Vol. IX an index has been planned for each year. It is to be arranged like the five-year index described in the following paragraph.

A general index to Vols. I to V was issued in 1930. It is divided into five parts. First there is an "Introduction" explaining the arrangement; next comes a list of the abbreviations used; then an "Analytical Index," which is actually the cumulated tables of contents of Vols. I to V; fourth, there is an alphabetical name index in French with many English, German, and Italian entries carrying cross references to the French equivalent; finally, there is a formula index occupying the major part of the book. Entries are based upon the empirical formula, the elements being arranged in an arbitrary order similar to that used in Gmelin, viz., rare gases, non-metals (H, O, N, F, Cl, Br, I . . .), carbon, and metals alphabetically by symbol. Full details are given in the Introduction. A second index covering Vols. VI to X is in preparation.

The Annual Tables are worthy of greater use. Their one disadvantage is that inherent in all such compilations, viz., that important data may have been overlooked.

"International Critical Tables of Numerical Data, Physics, Chemistry and Technology," McGraw-Hill Book Co., New York, 7 vols. plus an index, 1926–33. "Prepared under the auspices of the International Research Council and the National Academy of Sciences by the National Research Council of the United States. . . . " E.W. Washburn, editor-in-chief. The International Union of Pure and Applied Chemistry meeting in London, June, 1919, approved and delegated to the United States the responsibility for preparing "International Critical Tables" (ICT). In 1922 the Board of Editors selected Corresponding Editors in the various countries. They, in turn, with the assistance of advisory committees, recommended Cooperating Experts to compile critically and arrange "in suitable form, the

available quantitative information." The board tried "to secure the best man *available*" for each of the three hundred sections into which the work had been divided. The cooperating expert was furnished with the pertinent data that had appeared in the first five volumes (1910–22) of "Tables annuelles" and asked to select "in each instance the 'best' value which he could derive from all the information available, together, where possible, with an indication of its probable reliability."[1] Any data published before 1910 or after 1923 were collected by the cooperating expert through his own initiative.

The material submitted to the editorial board by each compiler was carefully edited, particularly in the interest of space conservation. When sufficient manuscript had been collected to fill a book of one thousand pages it was arranged and published. The original plan was to issue five volumes, but even with the most judicious use of space the editors soon found that at least two additional would be required to hold all of the data available. Ultimately the complete set of seven books, plus an index in pamphlet form, was published. Later Dr. C.J. West undertook the preparation of a more adequate index which was issued in 1933.

As the set now stands it is undoubtedly the most complete and comprehensive summary of numerical data ever attempted. Considering the funds available it is probably the best that could be obtained. There is, however, one criticism: Too frequently one encounters, instead of the specific figures needed, a formula which may be used to calculate them provided certain others can be found.

Use of ICT

When ICT is being used for the first time the following suggestions may be helpful:

The *Index* is not strictly alphabetical in arrangement; furthermore about five hundred pages of text have not been covered. Consult the "Introduction" (p. vii) for details.

The *Standard Arrangement* is described in Vol. I, p. 96, and in Vol. III, p. viii. Briefly, each element is arbitrarily assigned a "key number":

[1] For other instructions to compilers see the Introduction in Vol. I, p. xii.

1	2	3	4	5	6——11	12	13	14	15	16
O	H	F	Cl	Br	I——N	P	As	Sb	Bi	C

To locate a compound, write the key number for each element, omitting any combined water; then arrange the numbers in descending order (BiOCl → 15-1-4 → 15-4-1). The resulting group of numbers is called a "key formula." Next find the B table (see below) containing the desired information about the compound. Then proceed down the columns until the desired number combination is located (for BiOCl find first the fifteen section, within that 15-4, and within that 15-4-1).

"A" tables contain only *elementary substances.* They are arranged alphabetically by symbols.

"B" tables contain only *compounds.* They are arranged in inverse order of their numerical key formulas. When looking for a compound always consult the B table. It should be noted, however, that certain B tables omit compounds whose key formulas begin with 16 (carbon).

"C" tables contain *compounds* arranged according to their empirical formulas in the order C, H, then the remaining symbols alphabetically, e.g., $C_6H_4I_2O_3S$. The C tables contain no carbon compound whose key formula includes a number greater than 16. There is a table of contents at the beginning of each volume, and many of the sections start with an outline of their subject matter. References may cause a little confusion at first, but the following example will indicate their meaning:

Reference as it would appear at the end of a table:

(20) Kassler, *91*, **74**: 276; 28.

Significance

(20) —Reference number connecting the textual material with the bibliography

Kassler—Author of the article cited

91 —Key number to the name of the journal. Consult "Key to the Periodicals" at the back of the volume

74 —Volume number of the journal

276 —Page in volume cited on which original data can be found

28 —The last two figures of the year of publication of the volume specified

Restricted surveys

Fowle, F.E. (ed.), "Smithsonian Physical Tables," Smithsonian Institution, Washington, 8th revised ed., 1933. (Smithsonian Publication No. 3171)

The first edition of this book was prepared by Thomas Gray and issued in 1896. The seventh edition appeared in 1919. The last edition contains 270 more tables than the seventh. Some of the important sections are:

Units of measurement	Melting and boiling points
Mathematical tables	Thermal conductivity
Birge's physical constants	Expansion coefficients
Densities	Heat, specific, latent. . . .
Barometric tables	Spectrum wave lengths
Viscosity	Indices of refraction
Vapor pressure	E.M.F.
Thermometry	Electrical resistance
Electrolysis	Atomic structure
Dialectric constants	Radioactivity
Magnetic properties	Electron emission

Kaye and Laby, "Tables of Physical and Chemical Constants and Some Mathematical Functions," Longmans, Green & Co., New York, 8th ed., 1936.

Comey and Hahn, "Dictionary of Chemical Solubilities," The Macmillan Co., New York, 2d ed., 1921. "The aim has been to include . . . all analyzed inorganic substances, that is, all substances which do not contain carbon." There are some exceptions, however, for example carbonates and cyanides.

The arrangement is "practically that of the standard Dictionaries of Chemistry, whereby the compounds of metals with one of the nonmetallic elements have been classified under the metals, while the salts of the other acids, e.g., oxygen acids, have been arranged alphabetically under the acids." According to this scheme, barium chloride is entered under Ba, while barium chlorate is to be found under Chloric acid.

The data given for any compound are:

Solubility in water (data chronologically arranged).
Specific gravity of aqueous solutions.
Boiling point.
Solubility in other solvents.
Inorganic acids.
Alkali and salt solutions.
Organic solvents.

The work is a non-critical summary of the pertinent material in the literature down to Jan. 1, 1916. Since it was "found

impracticable to draw any distinction as to reliability between the various data given by different observers" quantitative measurements are quoted verbatim. There are also many statements of qualitative significance only. A brief history of solubility tables will be found in the preface. It states that the pioneer in the field was Prof. F.H. Storer's "First Outlines of a Dictionary of Solubilities of Chemical Substances" published about 1860. Between that date and the appearance of Comey and Hahn's book nothing similar had been attempted.

SEIDELL, A., "Solubilities of Inorganic and Organic Compounds," D. Van Nostrand Co., New York, 2d ed., 1919. A "Supplement," covering the period 1917–26, was issued in 1928. This book "considers only quantitative data and those only for the commoner substances. Dr. Seidell has followed the plan in most cases where there are several available solubility determinations of a substance of selecting and averaging the more reliable results, and embodying them in tables."[1]

The arrangement is alphabetical according to the first word in the name of a compound. Thus all calcium salts are grouped together. There is also a good subject index. References are given for all values quoted. The investigator's name and the date of the article appear with the data. The exact reference is given in the "Author Index."

Two special features of this book should be noted: (*a*) the section entitled "General Information" starting on p. v, particularly the part "Forms of Stating and Methods of Calculating Solubilities . . . " (pp. xi *et seq.*); (*b*) the division "Methods for the Determination of Solubility" (pp. 757 *et seq.*).

ATACK and WHINYATES (eds.), "Chemists' Year Book," Sherratt & Hughes, London, 1915– . The 1936 edition was edited by E. Hope.

BIEDERMANN, R., "Chemiker-Kalender," Julius Springer, Berlin, 1880– . 58th year, 1937; 3 parts in 2 vols. edited by I. Koppel. This was a very popular and unrivaled book for many years. Recently other handbooks have practically superseded it in the United States.

[1] COMEY and HAHN, "Preface."

Hodgeman, C.D., "Handbook of Chemistry and Physics," Chemical Rubber Publishing Co., Cleveland, Ohio, 22d ed., 1937. Started in 1914, more or less to advertise the wares of the Chemical Rubber Company, this handbook has gradually become their most important product. It contains a wealth of data in very convenient form.

Lange, N.A., "Handbook of Chemistry," Handbook Publishers, Sandusky, Ohio, 2d ed., 1937. For many years Doctor Lange collaborated with Professor Hodgeman in issuing the previously mentioned "Handbook of Chemistry and Physics." This new venture demonstrates that he has profited by the experience, because his book contains many excellent features. One example is the table "Physical Constants of Organic Compounds" which lists over four thousand of them and gives, in addition to the usual data, the volume and page in Beilstein IV where each is described. In other words, for the compounds listed Lange's table is also an index to Beilstein.

Olsen, J.C., "Van Nostrand's Chemical Annual," D. Van Nostrand Co., New York, 7th issue, 1934.

PATENTS

"The Congress shall have power . . . to promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries." U.S. Constitution, Art. 1, Sec. 8, Clause 8.

"Any person who has invented or discovered any new and useful art, machine, manufacture, or composition of matter, or any new and useful improvement thereof . . . not known or used by others in this country, before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country, before his invention or discovery thereof, or more than two years prior to his application, and not in public use or on sale in this country for more than two years prior to his application, unless the same is proved to have been abandoned, may upon payment of the fees required by law, and other due proceedings had, obtain a patent therefor." The patent statute. R. S. 4886; Statute Law **29**, 692. (Mar. 3, 1887.)

When a person builds, creates, devises, or prepares anything he is entitled to use the fruit of his toil if such use does not conflict with public welfare. This privilege is a common law right. Distinct from such rights are those granted by man-made rules called "statute laws." These, in general, limit, define, and restrict various activities ostensibly for the benefit of everyone. Owing to the difficulty of stating such regulations in terms unambiguous yet broad enough to include all situations, unforseen as well as contemplated, a third source of legislation has developed. The courts when applying statutes to individual cases give interpretations which later may be used as precedents for deciding similar cases. Thus three sorts of law are extant: common law, statute law, and court law. All are involved in patent law.

Patent defined

A patent is a contract between the federal government and an inventor in which the former agrees to give the latter the right

to exclude others[1] from making, using, vending, or selling his invention for a limited period (17 years) provided the inventor makes public a written disclosure in terms so clear that anyone "skilled in the art" can practice the invention after reading the description. Patents are authorized by statute law. They temporarily set aside certain common law rights for the purpose of encouraging the development of new industries rather than rewarding inventive genius. The value of a patent, therefore, consists not in the inducement to invent but in the protection afforded those who commercialize the invention. Historically the idea of a patent arose as an exception. In sixteenth century England a favorite way of filling the royal purse was to grant monopolies in exchange for cash. Because of flagrant abuse the Statute of Monopolies was passed in 1624 denying the king this power except to "the true and first inventor [of] any manner of new manufacture within this realm." The entire structure of modern patent law has been built on this reservation.

Value

Technically a patent is not a permit to do anything. It is construed by the courts as a statement from the Patent Office Commissioner that he believes the patentee has fulfilled all statute requirements and is therefore entitled to a patent. If the courts concur in this attitude they will uphold the patentee in preventing others from exploiting his invention. Therein lies the main advantage of a patented over a secret process (Macbeth Glass Case, 246 Fed.Rep. 696.). Suppose that Brown has discovered a simple method for obtaining gold from sea water. A valid patent will insure for him the assistance of the courts in enforcing a monopoly. On the other hand if he decides to maintain secrecy he may be denied even the right of entry.[2] Anyone else who independently discovers the process may enter into active competition with Brown.

Invention

Turning to the problem of what is patentable, the question can be answered by a consideration of the statute and interpreta-

[1] Cf. 264 Fed.Rep. 138. (This reference is in legal style. It means *Federal Reporter*, Vol. 264, p. 138.)

[2] The right to appeal to the court. Without a patent the courts may not permit him to present his case.

tions made by the courts. In the first place the law says "anyone who has invented . . . is entitled to a patent." To invent is to *discover or create something not existing or known before.*[1] All discoveries, therefore, are not patentable. For example, someone has said that the four greatest steps in human affairs have been the invention of the wheel and of writing and the discovery of fire and seeds (for the reproduction of plants). By the definition, neither discovery was patentable because both fire and seeds had existed before. Likewise the discovery of a law of nature, an element, electricity, etc., would not be patentable. Every invention is based on some discovery, but it does not follow that every discovery is an invention.

Novelty

The second requirement of the statute is that the invention be "new and useful." The definition of novelty is obvious from later statements in the law—"not known or used by others in this country . . . and not patented or described in any printed publication[2] in this or any foreign country before his invention or discovery thereof." On this point the court has said, "It may be a hardship to meritorious inventors, who, at the expenditure of much time and thought, have hit upon some ingenious combination of mechanical devices, which for aught they know, is entirely novel, to find that, in some remote time and place, someone else . . . has published to the world . . . a full description of the very combination over which they have been puzzling; but in such cases the Act, none the less, refuses them a patent."

Utility

The utility of an invention is seldom questioned by the Patent Office. Even a cursory examination of the Official Gazette will reveal many patents granted for devices, of but slight use, e.g., a glass armor, a hat tipper. Obviously the point would not be raised in court, because infringement proceedings cannot be instituted until the patented material has been used in some way by the defendant. The only important

[1] "Lost arts" are excluded from this restriction.

[2] It is immaterial whether the distribution has been limited or free, but the description therein must be sufficient to make experimentation unnecessary.

factor is that the invention must be useful in a social sense, not detrimental to public welfare. This eliminates gambling devices, check-raising machines, and the like.[1]

The five classes

The next feature of a patentable invention is that it must belong to one of the five[2] specified classes: *art*, *machine*, *composition of matter*, *manufacture*, or an *improvement* in any of the four. "Art" in the patent law is synonymous with process or method. It is a mode of treatment, a series of acts or correlated steps resulting in a product. The term "machine" includes any apparatus, device, or mechanical or physical structure that will perform some function. A "composition of matter" may be a mechanical mixture or chemical compound, e.g., thermite, dynamite, aspirin (U.S. Pat. 644,077). A "manufacture" is anything made by man that is not a machine or composition of matter.[3] An "improvement" invention is one involving a change in, or addition to, something previously invented. The alteration must, however, involve more than mere "mechanical skill," i.e., what the average person, familiar with the subject, might suggest. Today almost all patents issued are for improvements, the so-called "basic" or "pioneer" inventions being comparatively rare. Because of their importance in chemistry, certain of the classes just defined merit further consideration.

Art or process patents

As already stated, an "art" is a process or mode of treatment. It may consist of a single step or a combination of successive operations chemical or physical in nature, e.g., refluxing A and B in the solvent C to produce D which is removed by filtration, washed, and dried. An essential feature of a process is that it must be independent of the apparatus. An understanding of the reactions or scientific principles involved is unnecessary. Fur-

[1] Inventions useful in war are generally commandeered by the state.

[2] The amendment involving plants is not considered here.

[3] The U.S. Supreme Court, (404 O.G. 1043) ruled that " 'Manufacture' as well defined by the Century Dictionary, is the 'production of articles for use from raw or prepared materials by giving to these materials new forms, qualities, properties, or combinations, whether by hand labor or by machinery.' "

thermore, a new method need not yield a new result, because a process patent does not protect the product.[1] Alizarin had been extracted from madder for many years before the synthetic process was patented (U.S. 95,465). When a process consists of several operations, a change in their order or the addition of a step without alteration of the product is not patentable; neither is the addition of a reagent that merely acts as an adulterant. On the other hand if a step, claimed essential in the original patent, can be eliminated the resulting method is patentable provided there has not been a corresponding omission of function.

A variation in the conditions of a process may be patentable if a new and unexpected result is obtained. Charles Goodyear used 6 to 20 percent sulfur in vulcanizing rubber; Nelson Goodyear used 25 percent and over. Both obtained valid patents because the products were entirely different. The use of dilute potassium cyanide for the extraction of gold was held patentable because, in the prior art calling for concentrated potassium cyanide, the base metals were also dissolved. Stopping a well-known reaction at some intermediate stage to obtain a new and useful product has been declared patentable. Double use of a process may or may not involve invention. The dichromate method for tanning leather was held patentable even though it had been used previously for the dyeing of wool. The use of zinc dust for the precipitation of gold and silver was not sustained by the court, however, because zinc had long been used in an analogous way to remove copper from solution. Where catalysts are involved, the courts will usually consider valid a patent for each one found useful. Although the application of mono- and triphenylguanidine as accelerators in the vulcanization of rubber was well known, the courts sustained a patent for the diphenyl derivative because "the catalytic action of an accelerator cannot be forecast by its chemical composition, for such action is not understood and is not known except by actual test." (276 U.S. 358.)

Equivalents

Finally, the variation of a process by the use of equivalents is not patentable, the term "equivalent" being considered in the

[1] In England the reverse is true.

legal sense, i.e., with respect to function or result. Chemically, sodium hydroxide is generally conceded to be equivalent to potassium hydroxide, but in the reaction with a fatty acid they are not "legally" equivalent because the resulting soaps are different—hard and soft, respectively. In other words, no reagent is universally equivalent to another. Where a result cannot be foretold but must be ascertained by experiment the courts hesitate to uphold equivalency. Nevertheless it is a principle of law that a patent covers not only the exact class of process specified but also any process that a worker, skilled in the art, would regard as equivalent at the date of the patent application.[1]

Invoking this "doctrine of equivalents" has been very helpful in some cases but in others has resulted in disaster. It is perfectly clear that sulfuric acid, calcium chloride, and absolute alcohol are equivalent as desiccants.[2] It would be dangerous, however, to claim all liquid alcohols of the methane series as solvents in a particular operation if only methyl and ethyl alcohol had been tried, because the patent would be declared invalid should the iso members not function similarly [26 Fed. Rep. (2d) 305]. In a specific instance the patentee claimed "all zinc compounds" but described only zinc oxide, zinc hydroxide, and zinc carbonate in his specifications. It was later found that zinc sulfide and zinc chloride would not work; hence the patent was declared invalid. It is, therefore, important that all reagents claimed equivalent are actually so. On the other hand, it is equally essential that all equivalents be specified and claimed in order to guard against evasion of the patent. A certain patentee suggested the use of urea in his process. The patent was easily evaded by use of the isomer ammonium cyanate. In another case the sodium salt of dinitrophenol was substituted for dinitrophenol itself. The courts did not consider the two compounds equivalent. A mixture of manganese dioxide and tar was declared not equivalent to manganese carbide when used in a process for making steel. Equivalence of operation is

[1] Any equivalent discovered after that date is not protected because the patentee, under such conditions, would be enjoying the benefit of discoveries made by others.

[2] Their relative efficiency is not a factor.

another feature which must be considered. If a high-boiling solvent is satisfactory in a certain operation would it be possible to use one of low boiling point under pressure? In the preparation of cyanogen bromide, bromine might be added directly to potassium cyanide, or the halogen could be generated *in situ* by the use of potassium bromide, potassium bromate, and an acid. These steps might not be considered equivalent by the court.

Product patents

Hand-in-hand with process patents go product, i.e., composition-of-matter, patents.[1] In fact much of what has just been said regarding processes applies equally well to products. Where both the process and product are new and useful each may be protected by a separate patent. An old product made by a new process is, however, not patentable. Synthetic alizarin not being distinguishable from "natural" alizarin merited no protection. Change in the particle size or form is not invention unless more than a well-known result is obtained. Powdered glue was held not patentable even though more readily soluble than the massive form, but crystalline calcium carbide was granted protection because it could be used commercially in a gas generator whereas the previously known powdered form had been worthless for the purpose. For the same reason "pure" aspirin was found patentable, being useful as a medicine, whereas the product available before could not be employed therapeutically.

When a patent has been obtained for a mechanical mixture, furnishing the various ingredients in separate containers with directions for mixing has been declared an infringement. Similarly, addition of an inert substance to a product does not evade the patent.

As to the doctrine of equivalents in product patents, again the use or function factor predominates, although in several cases the court rulings may be perplexing to a chemist. As a resistance wire for a heater an alloy of 60% Ni + 40% Cr was held equiva-

[1] Technically there are no process or product patents. These terms are used extensively outside patent forms, however, hence are employed here, although they have no legal status.

lent to 55% Ni + 12% Cr + 15% Fe + 8% Mn (cf. 219 Fed. Rep. 210). On the other hand, in an explosive mixture, soluble nitrocellulose was not considered the equivalent of insoluble nitrocellulose. Retarding the setting of plaster of paris with marble dust and glue was "old art," but the substitution of calcium hydroxide for the calcium carbonate was considered new and patentable because the product was "highly satisfactory and successful in practice."

Improvement patents

Where improvement[1] patents are concerned it is far easier to say what is not patentable than to state what can be protected. An improvement must show inventive genius, not merely mechanical skill. A new, useful, and unexpected result must also be obtained. The dropping of steps or parts previously believed necessary or the elimination of a long-endured defect to give a simpler method or better product may be valid grounds for a patent. Multiplication of operations through duplication of parts; trivial changes such as alteration in size, form, arrangement, or proportions ordinarily do not merit protection.

Summary

Before the next phase of this subject is considered, the following summary may be helpful. An invention is an idea, not a tangible thing. A patentable invention is a mental result, but all mental results are not patentable. The concept alone is not sufficient. It must have been experimentally tested and found to attain the desired end.[2] Knowledge of the theory involved is not demanded. If the directions, when followed by one skilled in the art, give the result specified, an understanding of the cause and effect is not required. The essential factors in a patentable invention are that it must be new and useful, show inventive genius, and belong to one of the statutory classes, viz., art, machine, manufacture, composition of matter, or improvement. It is hardly necessary to say that failure to

[1] Machines and manufactures will not be discussed here.

[2] The courts have frequently ruled that disclosure of the idea or preparation of drawings is not sufficient. There must be experimental verification—the process must be tried, the machine must be built.

meet any one of these four requirements or any others listed in the act is an effective bar to a valid patent.

The next part of the patent act gives the inventor a period of two years (see Abandonment) after his invention has been embodied in which to study[1] his work and file application papers. Without going into details, it may be stated as a general rule that an application should be filed as soon as possible after reduction to practice in order to avoid or forestall interference proceedings in the Patent Office and to allow infringers no time in which to flood the market.

Abandonment

The question of abandonment may arise in three ways. First an inventor may not be diligent in completing his experimental work after conception of the invention. Here the court is usually lenient regarding its interpretation of the term "diligent." Second, after the invention has been completed the patent application may not be filed within a reasonable length of time—two years is considered ample. Third, after the application has been filed the applicant has six months in which to reply to each communication from the Patent Office. If he delays beyond that period his application is declared abandoned. Later he may reapply provided the delay can be proved unavoidable, e.g., due to severe illness. Finally, the last requirements of the statute, "Payment of fees required by law, and other due proceedings had," refer to the various fees[2] and the "Rules of Practice" as formulated by the Commissioner of Patents for the conduct of all business relating to the granting of a patent. These latter formalities of procedure concern the patent attorney, hence will not be discussed here further than to say that the steps, in the simplest case, are (*a*) the application for a patent consisting of five parts; (*b*) consideration by the Patent Office Examiner; (*c*) granting of the petition; and (*d*) issuance of the "Letters Patent" upon payment of the final fees. It is assumed, of course, that the entire transaction will be conducted by a

[1] See RIVISE, C.W., *The Chemist* **10**, 266 (1933). Rivise gives a good discussion of the "Steps Preliminary to Filing a Patent Application."

[2] All fees are listed in the pamphlet "General Information concerning Patents." See p. 245.

competent patent attorney familiar with the subject matter involved. A good patent, adequately securing the protection desired, is the work of an expert; a poor patent is expensive at any price and more likely to be a liability than an asset.

Inventor

Turning now from the problem of what is patentable to a consideration of the application and its consequences the question that first arises is: Who can obtain a patent? The Act says "anyone who has invented or discovered. . . ." This means the true inventor[1] or his duly appointed agent. In many cases this point cannot be decided until another has been settled: What is the invention?[2] Once clear about the nature of the invention the inventor should be readily identified, for he is the one who reduces the idea to practice. Another person may have suggested the problem, but he is not the inventor unless the one who takes the final step has merely the status of a skilled workman following directions. For example, if A tells B that someone ought to invent a process for making cold light and B, after experimentation, discovers a method, B alone is entitled to apply for the patent.[3] On the other hand, if A tells B to mix x, y, and z with the production of cold light as the objective, then A alone is entitled to apply should the combination give the desired result. Again, suppose A suggests the use of x and y while B advocates the addition of z. Then there results a joint invention, and both must apply as joint inventors.[4]

[1] The final decision in the "chromium plating" case was based on this point. The patent (U.S. 1,581,188) had been granted to Fink, but Udy was found to be the true inventor. [85 Fed.Rep. (2d) 577; 31 U.S.P.Q. 105 (Sept. 21, 1936); 86 Fed.Rep. (2d) 1015 (Dec. 7, 1936); affirms preceding decision.]

[2] Strange as it may seem, inventors have obtained patents, and then, years later, the true situation has been revealed. This comes about through failure to appreciate the fundamental principles employed to secure the result covered.

[3] "Mere suggestions or assistance from others will not invalidate the right of the patentee. To effect this the suggestion must furnish *all* information necessary to use the new process." Deller, Chap. III (see p. 242).

[4] Each joint inventor is entitled to all rights and privileges of the patent, and neither is responsible to the other. Anyone furnishing equipment or monetary aid, however, is not a joint inventor (cf. 226 Fed.Rep. 941; 229 Fed.Rep. 415).

Application

With the question settled respecting invention and inventor the next step is to consider the best way to secure maximum protection. When a process is involved, if both process and product are new, a product patent alone is considered better than a process patent alone. It would be well to protect both. Before this is done, the process should be subjected to exhaustive analysis to eliminate all unnecessary steps; reveal all equivalent reagents and operations; and determine ranges of concentration and working conditions, critical points, and the effect of impurities present in the reagents as commercially obtained (cf. p. 222). To be sure that no loophole remains, the role of competitor ought to be assumed, and the possibilities of evasion studied. These experiments should clearly disclose the limitations and potentialities of the process and thus form an adequate basis for drafting the essential parts of the application, viz., specification and claims.[1] While errors in theory do not invalidate a patent, inaccurate or inadequate directions in the specifications may be fatal.[2] Likewise no claim is allowed that is distinctly ambiguous, contains anything old or inoperative, or is broader than the disclosure in the specifications (66 Fed.Rep. 986). On the other hand, any invention not covered by the claims is "dedicated to the public." The patent claim, like a fence, defines the field of exclusion; hence "nothing can be more just and fair to the patentee and public than that the former should understand and correctly describe just what he has invented and for what

[1] "The specification is a written description of the invention and how it is made and used, and must be in such full, clear, concise and exact terms as to enable any skilled person to understand it. . . .

"The specification must conclude with a specific and distinctive claim or claims of the part which the applicant regards as his invention." ("General Information Concerning Patents," p. 5.)

[2] A certain patentee stated, apparently without experimental evidence, that "aniline can be treated with arsenic acid with or without heat." Later, an infringer's tests showed that practically no reaction takes place without heat. The patent was declared invalid because "the worker is clearly directed to do something useless." Similarly, in a patented process for the preparation of certain rhodamine dyes the presence of iron is essential. The patentee was unaware of this point until a competitor proved that the substitution of an enamel-lined autoclave for the iron one used by the patentee made the process inoperative. The patent was declared invalid.

he claims a patent." The value of a patent, therefore, "depends entirely on the wording of its claims. If these are skillfully drafted the patent may dominate a whole industry, and, if not, it may be almost valueless. . . . This difficulty applies with special force to chemical patents."

When the experimental work has been completed and the patent application properly executed the next step is presentation to the Patent Office. There the "date received" and application number are affixed; the invention is classified according to use and assigned to the proper division. An examiner makes a "prior art"[1] search. If he finds nothing he may recommend that the patent be granted. When a "Letters Patent" certificate is issued to the patentee[2] he should, within 12 months, apply for such foreign patents as he desires, otherwise the privilege is forfeited according to the International Convention. It must be clearly understood that the action of the Patent Office in granting a patent carries no implication as to its value. In fact a patent practically amounts to nothing more than a permit to ask the court for a decision in case of subsequent controversy. That decision, however, may mean life or death to the business activities of one contestant; hence, in this respect, a patent can be of inestimable value.

Assignment

Other rights of a patentee have been mentioned previously, but the subject merits further consideration in several respects. (*a*) Barring prior agreements a patent may be assigned to whomsoever the patentee designates. The assignee thereupon acquires all rights and privileges. (*b*) The patentee may assign a part interest to someone else but in so doing invites exploitation because the holder of an interest, no matter how small, has equal right with the patentee but is not responsible to him, hence may operate just as though he owned the whole patent. (*c*) A

[1] The granting of a patent by the Patent Office is based on a search of the available literature for "patentable novelty." The possibility of infringement of other patents is not considered. A good discussion of the work of the Patent Office examiners is given by Rossman in *The Chemist* **9**, 496–502 (1932).

[2] It is beyond the scope of this work to consider rejections, interference proceedings, appeals, disclaimers, and correction of errors by reissue.

patentee may license others to use his patent, placing such restrictions on the use as he may see fit. He can dictate as to the source of materials, selling price of product (*U.S. v. General Electric Co.*, 272 U.S. 476), duration of license, and territory in which operations may be conducted.

When making a contract the patentee should be sure that he does not give away his patent by agreeing to accept as payment some percentage of the selling price of all units sold or any other equally nebulous sum (cf. under Wright, p. 243). He should insist upon a guaranteed minimum royalty of a definite amount per year plus a certain fraction of the selling price of all units sold in excess of a specified number, or some other equally definite recompense, always remembering that the success of a patent depends largely upon the business heads behind it.

Employer-employee

Another aspect of patent ownership concerns the relations between employer and employee. In the absence of a specific contract any invention made by an employee using the employer's time and equipment belongs to the employee, but the employer is entitled to "shop rights."[1] If the employee develops the invention outside working hours in his own shop the employer has no legal claim upon the patent. Where employment is definitely for the purpose of doing research work all discoveries are the property of the employer, and all patents must be assigned to him. When a contract has been signed the employee must live up to the terms of his agreement, but the court will intervene in case of injustice to either party due to unfair interpretation of the arrangement.[2]

Infringement

In accord with statute law a patent gives certain exclusive rights to an inventor and simultaneously takes from others the corresponding common law rights. There is no implication,

[1] The right to make, use, or sell the patented material. This is a non-exclusive license which cannot be sold or transferred to another except as a part of the entire business.

[2] E.g., see *The New Jersey Zinc Co.* v. *Singmaster* as decided by the Circuit Court of Appeals, June 4, 1934. A note regarding the case appears in *Ind.Eng.Chem., News Ed.*, **6**, 250 (1934).

however, that the federal government will act as guardian of those rights. In fact the opposite is true. The patentee must in all cases, where he believes himself aggrieved, actively and diligently assert his rights. Since an invader has little to fear until the court has validated a patent, all important monopolies are confronted with the problem of infringement and consequent litigation very early in their history. Such actions are expensive, and the outcome is uncertain. The wise inventor avoids them whenever possible by adoption of a reasonable license policy. Any general discussion of patents would be incomplete, however, without some consideration of infringement.

The Patent Office grants a patent on the presumption that the inventor is entitled to the protection afforded. If, subsequently, anyone else, during the life of the patent, makes, uses, vends, or sells the patented material without the patentee's permission, he is said to have infringed. If he does not desist upon proper notification,[1] infringement proceedings may be instituted by the patentee as plaintiff in a federal court of equity.[2] There the patentee must present the evidence that he believes entitles him to the exclusive rights claimed. The defendant, accused of infringement, is given an opportunity to prove that the Patent Office erred in granting the patent. Then the judge considers the testimony submitted and decides that the patent claims[3] are (*a*) valid and infringed, (*b*) valid but not infringed, (*c*) invalid, therefore not infringed.[4] If the decision is in favor of the plaintiff a financial settlement may be included as well as an injunction restraining the defendant from further infringement.

Evidence

As regards the evidence mentioned in the last paragraph the plaintiff should be able to establish, to the satisfaction of the

[1] Patented material must be properly marked. Patented processes are protected through notifying all users by registered mail.

[2] The procedure is not so simple as described. For additional information see Thomas, "What to Do about Your Invention."

[3] Each claim stands on its own merits, the validity of one not necessarily affecting the status of any other.

[4] Decisions, giving the judge's interpretation of the points involved and the reasons for his conclusions, are naturally excellent sources of information regarding patent law as it is administered.

court, the dates of conception and reduction to practice. This might be accomplished for the date of conception by (*a*) a written statement of the idea signed and witnessed by two people who can be produced in the courtroom to verify their signatures or (*b*) the written description subscribed and sworn to before a notary or (*c*) an oral disclosure to two witnesses pledged to secrecy. In either case there should be no question as to the subject matter involved. Next, the properly authenticated experimental records (written with ink or an indelible pencil in a bound notebook having any missing pages accounted for) should be available to prove diligence in reduction to practice. The records, complete and clear, should show, in chronological order, the successive steps in working out the problem from the date of conception to the date of successful solution. All delays should be explained. Any discussion of the subject with anyone should be noted, and all bills for supplies should be on file in order that the chain of evidence may be as complete as possible. It must be clearly understood that the inventor will have the benefit of only such dates as he is able to establish (see p. 243 under Toulmin). Any later steps in the history of events will be covered by the application and correspondence with the Patent Office.

In addition to the preceding points the plaintiff must try to prove that his invention meets the statute requirements—that it is an art, machine, manufacture, or composition of matter; is new, useful, and shows inventive genius. The earlier discussion of the first six points may be considered sufficient for present purposes. If inventive genius is difficult to establish the court may accept such features as the satisfaction of a long-felt want, many unsuccessful efforts on the part of others to solve the problem, commercial success, or rapid and enthusiastic adoption.

Finally the plaintiff must submit evidence of actual infringement. This is often difficult to do. He may be sure in his own mind that his rights are being disregarded, but legal certainty is an entirely different matter. Access to the infringer's plant will undoubtedly be denied if a process patent is involved. Machines and products, when offered for sale, can be traced

to their manufacturer more or less readily. Circumstantial evidence should be used only as a last resort.[1]

Rebuttal

After the plaintiff has finished, the defendant will usually submit evidence attacking the validity[2] of the patent primarily on the grounds that the patentee is not the first and true inventor. Other secondary defenses may be used such as proof of abandonment, prior public use, and prior publication. Faulty specifications or claims are excellent loopholes. The defendant may insist that he is not using the process or product in question and may win the case on some trivial point chiefly because the patentee is bound by the limitations of his claims and cannot expand them. In a certain patent "heated fat liquor" was specified. The defendant used "cold fat liquor." The court absolved him from any guilt of infringement. On the other side a patent claim that is too broad is equally vulnerable. The Gans patent (U.S. 1,195,923) relating to zeolites for softening water contained claims so broad that they included prior art, hence were declared invalid.[3]

When both accuser and accused have completed their arguments a decision unsatisfactory to either party may be appealed. Proceedings started in a United States district court are thus transferred to a circuit court of appeals. If a number of conflicting district court and circuit court decisions have been obtained the United States Supreme Court may act as final authority.

[1] In the saccharin controversy the plaintiffs frankly stated that they did not know the defendant's method of synthesis. They asserted, however, that since they held 23 patents covering all the commercially practical methods the defendant must have infringed.

[2] Rossman lists 28 lines of defense.

[3] *Ind.Eng.Chem., News Ed.*, **2,** 9 (1930).

PATENT LITERATURE

"*Es ist überhaupt erstaunlich, was Alles in Amerika patentirt und welches uralten Verfahren immer wieder geschützt werden.*" FEHLING X, p. 615

The previous chapter was devoted to the legal aspects of patents, special attention being given to those of a chemical nature. Anyone wishing more details might start with the elementary article by Rossman[1] which is also valuable because of

TABLE 45.—PARTIAL OUTLINES OF ROSSMAN AND OF DELLER

Rossman "Law of Patents for Chemists"	Deller "Principles of Patent Law"
I. Introduction	History, Theory and Nature of Patents
Why the Chemist Should Know Patent Law	Classes of Patentable Inventions
To Patent or to Keep Secret	Persons Entitled to Letters Patent
II. Essential Patent Law Principles	Principles of Patentability
III. Obtaining the Patent	Acquisition and Termination of Letters Patent
IV. Rights under Patents	Remedy of Defective Patents
Essentials of a Valid Patent	Form and Construction of Patents
Patent Rights	Infringement of Letters Patent
Employer-employee Relations	Suits for Infringement
Enforcement of Patent Rights	Incidents of Ownership of Patents
V. General	Commercial Phases of Patents
Invention Records	Foreign Patents
Searching the Law	
The File Wrapper and Contents	
The Appraisal of Chemical Inventions	Appendix (largely statistical)
	General Bibliography
	Library List
Appendix	Indexes
Glossary of Terms	
Annotated Bibliography	
Index	

[1] The first seven citations have been classified and placed at the end of this chapter, p. 242.

the annotated bibliography covering both book and periodical literature. A more technical discussion is given by Rivise[2] who deals with the problem of patentability. This article is an excellent summary of the situation. Rossman's book[3] goes more deeply into the subject of patents for chemists, but he is careful to avoid the terminology of the legal profession. A list of the subjects covered is given in Table 45. There too will be found a summary of the topics in Deller's treatise[4] which, although

TABLE 46.—WHERE COPIES OF ISSUED PATENTS MAY BE PURCHASED*

Country	Send to	Price
Austria	Österreichisches Patentamt, Vienna (photostat copies: Bors & Müller, Wien I, Trattnerhof 2)	1s.
Canada	Commissioner of Patents, Ottawa (manuscript copies only)	Estimate on application
France	L'Imprimerie nationale, 27 Rue de la Convention, Paris XV	Fr. 5 + postage
Germany	Reichspatentamt, Gitschiner Strasse 97–103, Berlin S.W. 61 (patent class should be included)	0.9 RM
Great Britain	Comptroller-general, Patent Office, 25 Southampton Buildings, Chancery Lane, London, W.C. 2	1s. + ½d. postage
Japan	Teikoku Hatumei Kyôkae 10, 3-Tyôme, Marunouti, Kôzimati-Ku, Tokyo	4 sen + postage
Netherlands	Bureau voor den industrieelen Eigendom, Willem Witsenplein 6, den Haag	0.50 fl.
Switzerland	Bureau fédéral de la propriété intellectuelle, Berne	Fr. 1.20 for 10 pp. or less
United States	Commissioner of Patents Washington	10 cts.

* Data for several other countries are given in *Chemical Abstracts* **31**, No. 1, p. ii (1937).

addressed to chemists and metallurgists, is distinctly more technical than that by Rossman. Deller's appended bibliography (pp. 453–460) is especially valuable for those who care to investigate the legal literature: case reports, digests, etc.[5] Articles on special topics have been written by Rivise[6] and published in The Chemist. They deal with the applicant and

his application. Finally, Thomas[7] has prepared a summary of court decisions covering various points that have arisen in litigation. Actually his book is a "finding list" because a reference to the case report is given for practically every statement, a valuable feature for the more advanced student of patent law.

Obtaining specifications

Turning to the original patent literature,[1] i.e., the specifications and claims for issued patents (see p. 217), if one has the country of issue, number, date, and inventor's name for any particular patent he may purchase a copy from the source mentioned in Table 46. When a patent is "out of print" photostat copies may usually be obtained. Incidentally, various libraries in the United States have files of patents which are more or less complete (see Table 47).

TABLE 47.—SOME AMERICAN LIBRARIES HAVING FILES OF PATENT SPECIFICATIONS

City	Library	Patents available
Boston	Public	U.S., 1790– ; Brit., 1617– ; Ger. 1892– ; French, 1791–1900 (July)
Buffalo	Grosvenor	U.S., 1871 (May)–
Chicago	Public	U.S., 1871 (July)– ; Brit., 1617– ; French, 1791–1900 (July); Ger., 1914 (Jan.)–1933 (Mar.) 268,800–573,545
New York	Public	U.S., 1871– ; Brit., 1617– ; Ger., all but Nos. 302,901–455,200; French, 1902– ; Danish, 1894– ; Jap., 1905– ; Swed., 1885–
Philadelphia	Franklin Institute	U.S., 1790– ; Brit., 1617– ; French, 1791–1900 (June); Swiss, 1888–
Pittsburgh	Carnegie	U.S., complete; Brit., complete; Ger., 1913–14; French, 1791–1900 (July)
St. Louis	Public	U.S., 1871– (incomplete); Ger., 55,000– (approx. complete)
Washington	Patent Office	Complete files of U.S. and important foreign patents

The preceding statements naturally bring up the question of how to obtain the information required—number, date, patentee,

[1] It is very extensive. In the United States alone about a thousand patents are issued weekly of which about 18 percent are chemical in nature.

and, of still greater importance, subject. This leads directly to a consideration of the literature about patents which for present purposes will be divided into two groups: official and non-official. Under official literature will be considered publications, other than patents, of the various national patent offices: first our own, then two or three European, to indicate their similarities and differences. The non-official group will include other sources of information. Certain references, not mentioned in the text, will be inserted in the last section.

OFFICIAL LITERATURE

United States

Among the official publications of the U.S. Patent Office are the *Official Gazette*, "Annual Index," "Decisions of the Commissioner," and "Manual of Classification." The date of issue of any patent is the date of publication in the Official Gazette. This periodical (Vol. 1, 1872) now appears weekly on Tuesday. It contains a list of the patents, trade-marks, etc., granted on the Tuesday specified. The patents are arranged in numerical order. Each entry contains the patent number, title, name of patentee, date filed (i.e., date of application), a reproduction of any essential drawing, and the most important claim or claims (usually one, rarely more than two or three). At the back of each copy of the Official Gazette are three indexes:

a. Names of patentees alphabetically arranged.
b. Alphabetical list of inventions.
c. Classification of inventions according to use.

Given the patent number (Table 48), date of issue, patentee's name, or name of the invention, a patent can be quickly located in the Official Gazette. The lists of patentees' names and of inventions are cumulated in the Annual Index.[1] Of course the "List of Inventions" is of little value if the name assigned by the Patent Office is unknown. Furthermore it should be noted

[1] Down to 1926 this Index was bound with and formed a part of the "Annual Report of the Commissioner of Patents." Starting in 1920 and continuing down to date it has been issued as the "Index of Patents." The reason for the appearance under two titles during the overlapping six years is not apparent.

that there are very few cross references. Even though a patent bears an obscure or unusual title it may be entered only under

TABLE 48.—CHRONOLOGICAL LIST OF U.S. PATENT NUMBERS

1836 (July 28)	1*	1871	110,617	1906	808,618
1837	110	1872	122,304	1907	839,799
1838	546	1873	134,504	1908	875,679
1839	1,061	1874	146,120	1909	908,436
1840	1,465	1875	158,350	1910	945,010
1841	1,923	1876	171,641	1911	980,178
1842	2,413	1877	185,813	1912	1,013,095
1843	2,901	1878	198,733	1913	1,049,326
1844	3,395	1879	211,078	1914	1,083,267
1845	3,873	1880	223,211	1915	1,123,212
1846	4,348	1881	236,137	1916	1,166,419
1847	4,914	1882	251,685	1917	1,210,389
1848	5,409	1883	269,820	1918	1,251,458
1849	5,993	1884	291,016	1919	1,290,027
1850	6,981	1885	310,163	1920	1,326,899
1851	7,865	1886	333,494	1921	1,364,063
1852	8,622	1887	355,291	1922	1,401,948
1853	9,512	1888	375,720	1923	1,440,362
1854	10,358	1889	395,305	1924	1,478,996
1855	12,117	1890	418,665	1925	1,521,590
1856	14,009	1891	443,987	1926	1,568,040
1857	16,324	1892	466,315	1927	1,612,790
1858	19,010	1893	488,976	1928	1,654,521
1859	22,477	1894	511,744	1929	1,696,897
1860	26,642	1895	531,619	1930	1,742,181
1861	31,005	1896	552,502	1931	1,787,424
1862	34,045	1897	574,369	1932	1,839,190
1863	37,266	1898	596,467	1933	1,892,663
1864	41,047	1899	616,871	1934	1,941,449
1865	45,685	1900	640,167	1935	1,985,878
1866	51,784	1901	664,827	1936	2,026,516
1867	60,658	1902	690,385	1937	2,066,309
1868	72,959	1903	717,521		
1869	85,503	1904	748,567		
1870	98,460	1905	778,834		

* The number given is that of the first patent granted during the year specified. This table was compiled from the "Annual Report of the Commissioner of Patents for 1925," p. ix, and from the *Official Gazette* for the years 1926–37.

that title in the Index. Usually one must refer to the subject classification at the end of each weekly issue[1] of the Gazette and

[1] The Annual Indexes for 1916–20. inclusive, also contain a subject classification.

described in the "Manual of Classification of Patents—1929."[1] In this system all patentable subject matter is arranged on the basis of "essential functions or effects."[2] All inventions "having like functions, producing like products or classes of products and like effects or classes of effects, are purposed to be brought together . . . " and arranged in classes and subclasses (see Table 49). An examination of the Manual will reveal three important aids:

a. Classes alphabetically arranged.
b. Classes and subclass schedules.
c. Alphabetical index of class and subclass titles.

Two peculiarities of the grouping should be noted: "Compositions of matter are commonly classified with the processes and sometimes with the instruments for making them.[3] Processes limited to the use of particular ingredients for producing a specified composition are classified with the composition.

The utility feature of any subject having been determined with the aids mentioned, it should be possible to select the classes and subclasses under which patents relating to that subject might be placed. Possibly this can be done most easily by consulting first the alphabetical index for the specific name, then the class and subclass schedules for closely related headings (see Table 49). Next a search of the weekly classification index[4] for the corresponding class numbers ought to reveal all of the pertinent patents.

If in the course of an investigation a patent is found that appears, from the entry in the Official Gazette, to merit further study, the complete specification and claims may be examined at one of the depository libraries (Table 47), or a copy may be purchased from the Patent Office. Considerable additional

[1] Revisions are made occasionally and published in a special *Classification Bulletin.*

[2] Brearley's famous stainless steel patent is classified under "Cutlery."

[3] Thus carborundum might be classed under "Abrading compositions (51–280);" or "Chemistry compounds, carbides (23–208)"; or "Electrochemistry, synthesis of carbides (204–62)"; but according to this statement the proper place would be "Electric furnaces, products and related processes (13–36)."

[4] Since this method is tedious and uncertain at best, other ways will be described later in connection with the non-official literature.

TABLE 49.—SOME U.S. PATENT CLASSES AND SUBCLASSES INVOLVING SUBJECTS OF CHEMICAL SIGNIFICANCE*

Class		Class	
8	Bleaching and dyeing	254	Gas analysis
18	Plastics	254	Automatic
23	Chemistry	256	Volumetric
2	Gas separation and purification	257	Sampling devices
5	Composition	25	Plastic block and earthenware apparatus
6	Gas generating	30	Cutlery
7	Nitrogen and hydrogen mixtures	49	Glass
8	Fire extinguishing	52	Explosive, pyrotechnic and match compositions
14	Compounds	71	Chemistry, fertilizers
15	Rare element compound recovery	75	Metallurgy (70)†
25	Alkali-metal compound recovery	87	Oils, fats, and glue
50	Salts	91	Coating
51	Amphoteric metals	68	Processes
59	Boron	92	Papermaking and fiber liberation
61	Carbonates	95	Photography
75	Cyanogen	99	Foods and beverages (69).
85	Halogen	106	Plastic compositions
101	Nitrogen	37	Pyroxylin
114	Sulphur	40	Viscose and cellulose
139	Acids and acid anhydrides	127	Sugar, starch, and carbohydrates
183	Bases	134	Liquid coating compositions
203	Ternary oxy compounds	167	Medicines
204	Binary compounds	195	Chemistry, fermentation (70)
205	Halides	196	Mineral oils
209	Non-metals	202	Distillation
215	Halogens	204	Electrochemistry
230	Analytical and analytical control methods		Electrolysis
233	Catalysts	27	Tanning
239	Packing and preserving chemicals	31	Synthesis
252	Apparatus	252	Substance preparation
253	Analytical and analytical control	2	Absorbents
		4	Volatile-organic-liquid recovery
		6	Colloids and suspensoids

* For a complete schedule of classes 23 and 260 see Rossman, "The Law of Patents for Chemists," p. 247, or the U.S. Patent Office, "Manual of Classification" and the *Classification Bulletin* (No. 71 *et ante*) from which this summary has been prepared.

† Number of the *Classification Bulletin* in which the record will be found of a major change in the class since publication of the 1929 "Manual."

TABLE 49.—SOME U.S. PATENT CLASSES AND SUBCLASSES INVOLVING SUBJECTS OF CHEMICAL SIGNIFICANCE*—(*Continued*)

Class		Class	
8	Chemical purification of mineral substances	27	Azines
260	Chemistry—Carbon compounds	98	Esters
2	Condensation (unknown constitution)	108	Carboxylic acids
11	Metallo compounds	136	Aldehydes
14	Arsenic	142	Nitro compounds
15	Arseno	149	Ethers
17	Sulfurized products	153	Hydroxy derivatives
		160	Halogen derivatives
		167	Hydrocarbons
		172	Processes

* For a complete schedule of classes 23 and 260 see Rossman, "The Law of Patents for Chemists," p. 247, or the U.S. Patent Office, "Manual of Classification" and the *Classification Bulletin* (No. 71 *et ante*) from which this summary has been prepared.

information may often be obtained from a study of the contents of the "file wrapper," especially where there has been a difficulty in the granting of the patent. This file wrapper contains a complete history of the patent from the date of application to the date of issue. A copy can be secured by applying to the Commissioner of Patents.

British

Official publications of foreign patent offices are in general similar to those issued by the United States. In Great Britain the *Illustrated Official Journal* (*Patents*), corresponding to our Official Gazette, was issued each Wednesday from 1889 to 1931. Its successor *The Official Journal* (*Patents*) contains neither illustrations nor claims; consequently it is less useful. The "Illustrated Abridgements of Specifications" covers the years 1855–1930. For the period 1855–1908 (Series A) there are nine consecutive sets of 146 volumes each (one class in each volume) based upon the key of 1899. Starting in 1909 and extending to 1930 there are four consecutive sets of 271 volumes each (Series B). Since February, 1931, the number of groups has been forty (Series C). The "Abridgement Class and Index Key" explains the arrangement of these compilations. It should always be consulted before starting a search, because it contains information not repeated in the annual indexes. The third edition of the key (1899) describes the 146 divisions used

down to 1909; the fourth edition (1910) explains the 271 divisions used from 1909 to 1930 (see Table 50).

Finally, there are two important indexes, the "Fifty Years Subject Index" for 1861–1910 in 271 volumes and the "Name Index," Vol. 1 of which covers the period 1617–1852. Since 1910 the subject index and since 1889 the name index have been continued in the Official Journal.

TABLE 50.—BRITISH CLASSIFICATION OF PATENTS.* SOME CLASSES OF CHEMICAL INTEREST

1855–1908: Series A

- Class 1. Acids, alkalis, oxides and salts. Inorganic
- 2. Acids and salts, organic and other carbon compounds (including dyes)
- 90. Non-metallic elements
- 91. Oils, fats, lubricants, candles and soap
- 95. Paints, colours and varnishes
- 98. Photography
- 127. Sugar

1909–1930: Series B

- Class 1. (i) Chemical processes and apparatus
  - (ii) Inorganic compounds other than metallic oxides, hydrates, oxyacids, and salts (including alkali manufacture and cyanogen compounds)
  - (iii) Oxides, hydrates, oxyacids and salts, metallic (other than alkali) manufacture and cyanogen compounds
- 2. (i) Acetylene
  - (ii) Cellulose, non-fibrous, and cellulose derivatives
  - (iii) Dyes and hydrocarbons and heterocyclic compounds and their substitution derivatives
- 15. (ii) Dyeing
- 82. (i) Metals, extracting and refining, and alloys
- 90. Non-metallic elements
- 91. Oils, fats, etc.

1931– : Series C

- Group III. Chemistry, Inorganic. Distillation. Oils. Paints
- IV. Acetylene. Cellulose. Chemistry, Organic. Dyes and dyeing
- V. Cements. Indiarubber . . .
- VI. Beverages. Food production. Medicine . . .

* From "Abridgement of Specifications," 33, IX (at back) (1921), and *The Official Journal (Patents)* No. 2196 (Feb. 18, 1931).

German

The German Patent Office publishes two journals weekly. The "Patentblatt" and its supplement "Auszüge aus den Patent-

schriften" appear each Thursday. The Patentblatt contains first a list of applications;[1] second, a list of patents granted; and then applications withdrawn, patents refused, alterations, and finally cancellations.[2] All of this material is arranged, within each division, according to the German system of classification. Each entry contains the classification number, application

TABLE 51.—CHRONOLOGICAL LIST OF BRITISH PATENT NUMBERS

1915	1*	1923	190,731	1931	340,201
1916	100,001	1924	208,731	1932	360,001†
1917	102,812	1925	226,571	1933	380,001
1918	112,131	1926	244,801	1934	400,001
1919	121,611	1927	263,501	1935	420,001
1920	136,852	1928	282,701	1936	440,001
1921	155,801	1929	302,941	1937	
1922	173,241	1930	323,171		

* Before 1915 numbering started at 1 each year.

† Numbers for the last 5 years were furnished by the Science and Technology Division of the New York Public Library which calls attention to the fact that dates of acceptance of specifications are not always consecutive with patent numbers.

number, name and address of the inventor, title of the patent, and its date. The "Auszüge" (Abstracts of Patent Texts) corresponds more nearly to our Official Gazette. The arrangement is, however, according to class and not number. An explanation of the classes is to be found in "Gruppeneinteilung der Patentklasse," which contains almost 19,500 subdivisions. Class 12 is one of particular interest to chemists (see Table 52).

There are several indexes, but the one of major importance is the annual "Verzeichnis der erteilten Patente." This "Verzeichnis" is divided into five sections:

(*a*) "Chronologische Uebersicht der Patente" which lists patents in numerical order and gives the classification of each.

[1] All German applications are open to public inspection for 2 months before final action is taken. During this period anyone may obtain a copy of the specification and file objections. If sustained, the patent is not granted. Once issued, the validity must be attacked within five years; otherwise the right is abandoned.

[2] In Germany, as in many other foreign countries, there is an annual tax on a patent increasing with the age of the patent. If not paid, the monopoly is cancelled.

(*b*) "Systematische Uebersicht der Patente" arranges patents by classes and gives the number, title, date, and cross reference to the "Auszüge."

(*c*) "Alphabetisches Namenverzeichnis der Patentinhaber" contains in addition to the inventor's name, the patent number, class, and a cross reference to the "Systematische Uebersicht."

TABLE 52.—SOME DIVISIONS OF THE GERMAN PATENT CLASSIFICATION

Class 12			Chemical processes and apparatus in so far as they are not considered in special classes
	Subclass 12*a*		Cooking processes and vessels for chemical work evaporation, concentration, distillation (except dry distillation of wood under *r* and Class 10*a*)
		1	Heating for chemical purposes
		2	Evaporation or concentration . . .
	12*b*		Calcination, melting . . .
	12*c*		Solution, crystallization, concentration of liquids
	12*d*		Clarification, separation, filtration
	12*e*		Absorption and purification of gases and vapors . . .
	12*g*		General pure chemical processes of the chemical industry
	12*h*		General electrochemical processes and apparatus
	12*i*		Metalloids and their compounds
		2–10	Halogens
		11–16	Oxygen and its compounds
		17–25	Sulfur and its compounds
	12*k*		Ammonia, cyanogen, and their compounds
	12*l*		Alkali metal compounds
	12*o*		Hydrocarbons, alcohols, aldehydes, ketones . . .
	12*p*		Ring compounds containing nitrogen . . .
	12*q*		Amines, phenols, naphthols, aminophenols . . .
	12*r*		Tar distillation . . .
Class 30*h*			Medicinals, cosmetics . . .
Class 48			Chemical preparation of metals (electrodeposition, etc.) . . .

(*d*) "Alphabetisches Sachverzeichnis" includes the patent number, classification, and cross reference to the "Systematische Uebersicht."

(*e*) "Verzeichnis der Patente" which is a list of all patents in force arranged by class and by number. Given the patent number, patentee's name, or the subject by use of the "Verzeichnis" a patent may be quickly located. Table 53 will be of help in case the number alone is known, because it tells which year of the "Verzeichnis" to consult.

Except for minor details[1] the patent office literature of other countries is similar in nature to that of at least one of the three nations mentioned in the preceding paragraphs. The Germans

TABLE 53.—CHRONOLOGICAL LIST OF GERMAN PATENT NUMBERS

1877–78	1	1898	96,191	1918	296,326–311,090
1879	4,391	1899	101,761	1919	296,424–318,791
1880	8,801	1900	109,191	1920	296,478–333,470
1881	12,767	1901	117,975	1921	297,918–348,890
1882	17,106	1902	128,483	1922	296,475–369,600
1883	21,237	1903	139,093	1923	297,241–390,120
1884	26,085	1904	149,057	1924	296,958–408,310
1885	30,544	1905	158,246	1925	408,311
1886	34,562	1906	167,846	1926	424,191
1887	38,570	1907	181,276	1927	439,681
1888	42,452	1908	194,526	1928	454,941
1889	46,375	1909	206,136	1929	470,541
1890	50,781	1910	218,131	1930	490,751
1891	55,461	1911	230,231	1931	517,492
1892	61,011	1912	242,871	1932	543,356
1893	66,911	1913	255,951	1933	569,561
1894	73,341	1914	269,471	1934	591,301†
1895	79,621	1915	281,821	1935	608,301
1896	85,341	1916	290,011	1936	624,441
1897	90,751	1917	296,282–303,681*		

* From 1917 to 1924 there was considerable overlapping of the numbers apparently through delay in actually granting patents to which numbers had been assigned. During the period 1925–32 there was less confusion, since only the following were issued during the year stated in addition to the numbers given in the table:

1925	301,647 and 365,340*a*
1926	305,080
1927	406,565; 418,418; 418,909; 423,164; 432,658; 435,458
1928	445,293
1929	365,340*a*; 451,537; 458,880; 466,051; 468,383
1930	11 numbers between 468,976 and 490,711
1931	12 numbers between 470,839 and 517,451
1932	32 numbers between 494,090 and 543,359

† Numbers for the last three years were furnished by the Science and Technology Division of the New York Public Library.

with their characteristic thoroughness have set up a system that has been used as a model in many other lands. Any further discussion, therefore, would be largely repetition.

[1] Anyone wishing them should consult the article by Julian F. Smith mentioned in the footnote, p. 248.

NON-OFFICIAL LITERATURE

Worden's index

One of the important non-official keys to patents is Worden's "Chemical Patents Index" which covers only United States issues during the 10 years 1915–24. Volume I contains an alphabetical list of all patentees. The subject index is started in this volume and completed in the succeeding four volumes. Under each entry will be found the number of every patent in which the indexed word is mentioned. Although the naming of organic compounds follows essentially the system used in Chemical Abstracts there are certain peculiarities. Consequently the "Prefatory Statement" in Vol. I should be consulted before any extensive use of the Index is attempted.

Dyes

A more restricted discussion of patents is Friedländer's "Fortschritte der Teerfarbenfabrikation und verwandter Industriezweige."[1] This work embraces the period 1877–1930, and the material in each of the 17 volumes is arranged according to subject, e.g., azo dyes, indigo dyes. At the beginning of each division there is a general discussion of the group which is followed by a reproduction of every accepted patent and the claims of every patent application included in the class. Little space is devoted to foreign patents. Starting with Vol. V there is, however, a list that gives the number of each American, British, and French patent mentioned in the text. Every volume has a detailed table of contents, a subject index, patentee index, and list of patent numbers. This compilation is well known and widely used.

Inorganic Industry

Complementary to Friedländer is Brauer and D'Ans, "Fortschritte in der anorganisch-chemischen Industrie." This series,

[1] Volume XVI carries the subtitle "Verbindungen ohne Farbstoffcharakter der organischen Technologie. Organische Farbstoffe. Verfahren der Faserveredlung. Färbe- und Druckverfahren. Celluloseverbindungen. Plastische Massen. Harze. Gerbstoffe und Hilfsmittel der Textilindustrie. Mittel zur Schadlingsbekampfung. Pharmazeutische Präparate. Hormone. Vitamine. Sera. Impfstoffe." Not all of these topics are considered in the earlier volumes.

in four volumes, is now complete from 1877 to 1932: Vol. I, 1877–1917; Vol. II, 1918–23; Vol. III, 1924–27; Vol. IV, 1928–32. The arrangement is similar to that of Friedländer. The patent classes dealing with inorganic compounds are discussed in order according to the German system. Each division contains, first, a brief review of the field, important foreign patents, and recent literature; then there is a reproduction of each German patent. If foreign protection has also been granted, the patent number is mentioned. "This work presents the easiest way to a quick acquaintance with the German patent state of the inorganic chemical art."

Drugs

Another excellent summary of patent literature is Houben's "Fortschritte der Heilstoffchemie" the first part of which is entitled "Das deutsche Patentschriftwesen." This division—six volumes have been published—considers the patents in Class 12 *i*, *o*, *p*, *q* and Class 30*h*. The arrangement is the same in all volumes. After the introduction there is a list of patent numbers grouped according to class and subclass. Next comes a survey of each section attempting to interpret the patents and give their theoretical basis. Then the patents themselves are reproduced in numerical order. Finally there are author and subject indexes.

Winther's digest

A few years ago Winther published his "Patente der organischen Chemie" in three volumes. The first volume is a digest, by subjects, of German patents and applications from 1877 to 1905 relating to organic compounds not dyes. The second discusses dye patents of the same period. Volume III contains (*a*) a list, in numerical order, of the patents considered together with the numbers of each patent if also issued in the United States, Great Britain, France, Austria, or Russia; (*b*) numerical lists of organic patents, granted from 1895 to 1908, in each of the countries just mentioned with the patentee's name, date of issue, and number of the corresponding German patent; (*c*) alphabetical list of patentees; (*d*) a subject index; (*e*) a list of trade names with data concerning the manufacturer,

chemical composition, patent involved, and references to other pertinent literature.

PATENT SEARCHES

In conclusion, the problem of patent searches depends entirely on the objective. If one wishes to acquire a nodding acquaintance with patent literature and its potentialities[1] the matter is fairly simple. At the other extreme is the preparation of a bibliography to be used in connection with an important infringement suit. Although such work can be started anywhere it cannot be considered complete until a patent bibliographer, expert in the field of chemical claims, has made a thorough examination in the Patent Office library, the New York Public Library, or some other center having equal facilities. Somewhere between the two extremes are searches made (*a*) before starting research work, (*b*) before applying for a patent, (*c*) by the Patent Office examiner, (*d*) by possible infringers. With two exceptions all of these investigations are beyond the scope of this book. The discussion here will be restricted, therefore, to searching for a patent, given the number or patentee's name, with just an introduction to the more difficult task of finding issues dealing with a particular subject.

Starting with a patent number, the first step is to get some notion of the year the patent was granted (see the "Chronological Tables" in this chapter), then refer to the official journal of the country concerned. The United States and British patents are arranged numerically; many of the others, according to a system of classification; but number indexes are usually provided. If the official journal is not available, various other aids may be consulted (see Table 54). The search should ultimately reveal the patentee's name, date granted, and at least the field of operation, perhaps also an abstract. If sufficiently attractive to warrant further investigation, the specification and claims may be procured as already described.

When the quest starts with only the inventor's name, his nationality will suggest which official journal to consult first. Since this information may be difficult to obtain, the author indexes of Chemical Abstracts, the Zentralblatt, British Chemical

[1] Cf. Smith, J.F., *Ind.Eng.Chem.*, **16**, 527 (1924).

TABLE 54.—PATENT-FINDING AIDS

Publication	Countries included	Years	Aids
Official Gazette	U.S.	1872–	Arranged numerically. Annual patentee and title index
Chem. Abstracts	U.S.	1907–	Fortnightly and annual patentee (starred names in regular author index). Number index 1912–14
Worden's Chem. Patent Index	U.S.	1915–24	Patentee and subject indexes
Official Journal (Patents)	Gt. Britain	1889–	Arranged by classes
Abridgments	Gt. Britain	1855–1930	Arranged by classes, one volume per class
Name Index	Gt. Britain	1617–	Annual index by name
Fifty Year Subject Index	Gt. Britain	1861–1910	Arranged by classes, one volume per class
J.Soc.Chem.Ind	Gt. Britain, U.S., France, Germany	1901–25	Annual patent number index
J.Chem.Soc	Gt. Britain	1913–25	Annual patent number index
J.Soc. Dyers & Colourists	Gt. Britain	1884–	Monthly list of British and foreign patents
B.C.A	Gt. Britain	1926–	Annual patent number index
Patentblatt	Germany	1877–	Class and subclass order
Auszüge	Germany	1880–	Class order
Verzeichnis	Germany	1877–	Annual indexes; numerical class, patentee, subject
Chem.Ztg	Germany, U.S., Gt. Britain, France	1895–1906	Semi-annual number index to 1901, thereafter annual
Chem.Ztg. (Chemisch-Technisches Uebersicht)	Germany, *et al.*	1907–	Annual number index
Berichte	Germany	1894–97	Annual number index
Chem.Zentralblatt	Germany, *et al.*	1897–1920	Semi-annual number index
		1921–	5-year cumulated number index

TABLE 54.—PATENT-FINDING AIDS.—(*Continued*)

Publication	Countries included	Years	Aids
Wagner's Jahresbericht	Germany	1889–	Annual numerical index for organic and also for inorganic
Patentregister	Germany	1878–1924, 1925–35	Lists German patents in numerical order
Angew.Chem	Germany	1890–1918	Annual number index. Application index by classes
Patent Blatt	Austria	1899–	
Recueil de brevets d'invention	Belgium	1854–	
Brevets d'invention	France		
Chimie & industrie	France, Germany, U.S., England, Russia, Canada, Norway, Sweden		
L'Industrie chimique	France	1914–	
Patentliste	Switzerland	1889–	
Rowe's Color Index	Gt. Britain, U.S., Germany, France, Switzerland	Up to 1928	Dye patent numbers chronologically arranged
Friedländer's Fortschritte	Germany	1877–1930	Subject, patentee, numerical indexes. Cumulative numerical index
Bräuer & D'Ans	Germany	1877–1926	Subject, patentee, numerical index
Houben's Patentschriftwesen	Germany	1877–1928	Number, class, name, subject index
Winther	U.S., Gt. Britain, France, Austria, Russia	1877–1905	Numbers of patents issued in other countries when initially protected in Germany. Patents of each country by number, date, class. Patentee and subject indexes

Abstracts, and Chimie & industrie may be helpful. If not, the patentee indexes of the various patent offices should be examined, probably in the following order: United States, British, German, French, Swiss, Austrian, others as encountered.

When a name is being searched for, two questions should always be kept in mind: (*a*) Is the name spelled correctly? (*b*) Is it really that of the patentee? Often it is advisable to confirm these points before much time is spent on the problem, for it is possible that Brown should be Braun and that White was the assignee, not the patentee.

Lastly, given a subject, how can one locate the relevant patents? As previously intimated, not by searching the official title indexes. An inventor desires to obtain the maximum protection possible. If, therefore, he can hide his patent by giving it an obscure name the artifice is considered entirely legitimate. Furthermore, he is aided by the patent indexers because they endeavor to enter a patent but once and do not include cross references. Incidentally, they are concerned about the appropriateness of a title only from the standpoint of function or use of the thing patented.[1] Mellon (p. 59) suggests that the subject indexes of abstract journals also may be unreliable. He says, "It has been the author's experience that the subject indexes of the abstracting journals are not always dependable when searching for abstracts on patents. The abstract is included, but no reference to it can be found in the index." As a result of this situation it is believed that a fair start on a subject search can be made by going first to the various official indexes based upon systems of patent classification[2] (see earlier descriptions).

Two non-official compilations not particularly concerned with patents, yet containing many patent references, are Ullmann's

[1] Any issue of the *Official Gazette* will furnish numerous examples. The writer has at hand U.S. Pat. 1,840,445 which is entitled "Titration Method Tablet Therefor." With no more information would anyone suspect that it describes a simple method for determining the strength of a hypochlorite solution?

[2] A complete list of patent numbers by classes and subclasses is available at the Patent Office in Washington. The Carnegie Library at Pittsburgh has a list "for 48 (U.S.) classes, mainly in the fields of chemistry and metallurgy." Other libraries may possess similar aids.

TABLE 55.—LITERATURE DEALING WITH PATENTS BY SUBJECTS

Subject	Sources
Acetaldehyde	Ullrich, A., *Metallbörse* **21**, 315, 363, 413 (1931)
Acetic acid	Klar, N., "Technologie der Holzverkohlung . . . ," Julius Springer, Berlin, 1910, pp. 404–19
Cd plating	Rossman, J., *Metal Ind.* (*N.Y.*), **27**, 330–32, 375–76 (1929)
Carbon (activated)	Krczil, F., *Kolloid-Z.*, **55**, 367–71; **56**, 111–6 (1931)
Cement (manufactured)	Rossman, *J.Rock Products* **34**, 46–50 (1931)
Cr plating	Schneidewind, R., "A Study of Patents Dealing with the Electrodeposition of Chromium," University of Michigan, Ann Arbor, *Eng.Research Bull.*, **8**, 1927.
Dyes	Curtis, C.A., "Artificial Organic Pigments," Sir Isaac Pitman and Sons, London, 1930, pp. 122–166. Doyle, Friedländer, Heumann, Lange, Rowe, Schultz
Dyes, rayon	Winther; Brightman, R., *Ind.Chemist* **7**, 4 (1931)
Methanol	Dersin, H., *Chem.-tech.Rundschau* **44**, 126–8, 176–8(1929). CH_3OH from CO + H
Petroleum	Carpenter, J.A., *J.Inst.Petrol.Tech.*, **16**, 306–12 (1930)
Petroleum (cracking)	Egloff, Lowry, Schaad, *ibid.*, pp. 133–246
Phenol (synthesis)	Melanoff, I.S., *Plastics* **6**, 23, 30, 86, 97 (1930)
Plastics	Aladin, *Plastics* **7**, 142 *et seq.* (1931). Cellulose acetate
Proteins	Altpeter, "Patentliteratur der Eiweiszstoffe," Allgemeiner Industrie-Verlag, Berlin, 1932
Rayon	Suvern, K., "Die künstliche Seide," Julius Springer, Berlin, 5th ed., 1st suppl., 1931
Waxes	Fischer, E.J., "Wachse, wachsahnliche Stoffe . . . ," T. Steinkopf, Dresden and Leipzig, 1934. Vol. 30 of Rassow's "Technische Fortschrittsberichte"
Zinc oxide	New Jersey Zinc Co., *Research Bull.*, May, 1930. Zinc oxide as a rubber pigment

* This table calls attention to a variety of patent bibliographies for the purpose of assisting anyone interested in the arrangement of such material.

Encyclopedia and the National Research Council's "Bibliography of Bibliographies." Next, special treatises should be examined, e.g., Friedländer, Doyle, Heumann, and Rowe for dyes; Bedford and Winkelmann for rubber; Worden for cellulose esters, etc.

(see Table 54). Finally, the various subject indexes of abstract and patent journals might be examined. Of course the magnitude and importance of the search will dictate the stopping point. A cursory inspection would cover only the last named sources, but no serious attempt would stop short of all groups suggested.

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4. DELLER, A.W., "Principles of Patent Law for the Chemical and Metallurgical Industries," Chemical Catalog Co., New York, 1931. The bibliography of legal sources is very good.
5. "Law Books and Their Use," Lawyers Cooperative Publishing Co., Rochester, N.Y., 1930. Gives a more complete discussion of legal sources than Deller.
6. RIVISE, C.W., *The Chemist* **9**, 207–11 (1932). Deals with the applicant for a patent. "Whose name is to go on a patent." *Ibid.*, **10**, 266–75 (1933). "Steps preliminary to filing a patent application." This is an excellent article. It should receive more publicity.
7. THOMAS, E., "The Law of Chemical Patents," D. Van Nostrand Co., New York, 2d ed., 1927.

HAMSON, C.J., "Patent Rights for Scientific Discoveries," Bobbs-Merrill Co., Indianapolis, Ind., 1930.

LOTSCH, J.L., "Walker on Patents," Baker, Voorhis & Co., New York, 6th ed., 2 vols., 1929. The standard reference on patents. Contains a list of all pertinent Supreme Court cases and a brief summary of each decision.

MÜLLER, E., "Chemie und kontinentales Patentrecht," Verlag Chemie, Berlin, 1932.

POTTS, H.E., "Patents and Chemical Research," University of Liverpool Press, Liverpool, England, 1921. Although written from the English standpoint there is much of value for American inventors.

Idem., "Patents: Invention and Method," The Open Court Company, London, 1924.

RHODES, F.H., "Patent Law for Chemists, Engineers and Executives," McGraw-Hill Book Co., New York, 1931.

RIVISE, C.W., "Preparation and Prosecution of Patent Application," The Michie Co., Charlottesville, Va., 1933.

RIVISE and CAESAR, "Patentability and Validity," The Michie Co., Charlottesville, Va., 1936.

SINGER, B., "Patent Laws of the World," published by the author, 28 E. Jackson Blvd., Chicago, 5th ed., 1930. Well known.

STRINGHAM, E., "Patent Claim Drafting," Pacot Publications, Washington, 1930. Addressed to the legal profession.

THOMAS, E., "What to Do about Your Invention," Leisure League of America, New York, 1934. Number 5 in the Leisure League Little Book series; this pamphlet (*ca.* 100 pp.) contains a good discussion of the general subject.

TOULMIN, H.A., "How to Keep Invention Records," D. Appleton and Co., New York, 1920.

Idem., "Patent Law for the Inventor and Executive," Harper and Brothers, New York, new ed., 1933.

Idem., "Graphic Course of Patentable Invention," D. Van Nostrand Co., New York, 1935.

Idem., "Invention and the Law," Prentice-Hall, New York, 1936. Contains a bibliography of about 500 references in addition to the case citations in the text.

VOJÁČEK, J., "Survey of the Principal National Patent Systems," Prentice-Hall, New York, 1936.

WEIDLICH and BLUM, "Das Schweizerische Patentrecht," Verlag Stämpfli & Cie., Bern, 9, 1934.

WRIGHT, M., "Inventions, Patents and Trade-marks—Their Protection and Promotion," McGraw-Hill Book Co., New York, 1933. See especially "Don'ts for Inventors," pp. 175 *et seq.*

Journal Articles

The Journal of the Patent Office Society, Vol. I, 1918. Published monthly. Frequently contains pertinent articles. The first decennial index appeared in Vol. XI (1928).

BIESTERFELD, C.H., *J.Pat.Office Soc.*, **2**, 598–608 (1919). A digest of cases on the breadth and scope of chemical claims.

CARR, W.G., *Elect.J.*, **21**, 435–8 (1924) Enforcement of Patent Rights.

FENNING, K., *Ind.Eng.Chem.*, **25**, 343 (1933). Discusses employer-employee relations.

ULLRICH, A., *Angew.Chem.*, **46**, 537–8 (1933). The granting and annulment of patents.

SADTLER, R.E., *Ind.Eng.Chem.*, *News Ed.*, **10**, 133 (1932). Canadian Patent laws and practice for the chemist. Cf. MacRae, *J.Soc.Chem.Ind.*, 39, 176R (1920).

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VAN DOREN, L., *J.Chem.Education* **6**, 123–8, 536–40, 966–72 (1929). What the Chemistry Student Should Know about Patent Procedure. The first part is historical; the second discusses the Patent Office personnel and gives a bibliography; the third, and best from the standpoint of this discussion, covers the preparation of a patent application.

Moulton, A.B., *Ind.Eng.Chem.*, *News Ed.*, **6**, 7 (1928). Basic requirements of a patentable invention.

Potts, H.E., *Chemistry & Industry*, **47**, 636–43, 664–8 (1928). Patents in Colliod Chemistry.

Thomas, E., *Ind.Eng.Chem.*, **19**, 176–80, 315–7, 426–9 (1927). Outlines law of chemical patents.

Ehrhardt, E.F., *J.Soc.Dyers Colourists* **42**, 17–23 (1926). Patent law in the dyeing industry.

Toulmin and Heywood, *Chem.Met.Eng.*, **32**, 157–8 (1925). Consider patentability of ideas and possible infringement.

Barrows, F.E., *Ind.Eng.Chem.*, **15**, 80–1 (1923). Patent right.

Mastick, S.C., *Ind.Eng.Chem.*, **7**, 789–97, 874–82, 984–91, 1071–81 (1915). A series of lectures on patent law in chemistry.

OFFICIAL LITERATURE

United States[1]

The Official Gazette of the United States Patent Office, 1872– , published weekly on Tuesday.

"Index of Patents," published annually under this title since 1920 (see entry following). There is also an Index, in 3 vols., covering the period 1790–1873. It was published in 1874.

"Annual Report of the Commissioner of Patents," published annually, 1836– . In addition to statistical information this report contains the Annual Index down to 1926.

"Decisions of the Commissioner of Patents and of the United States Courts in Patent and Trade-mark and Copyright Cases," published annually. Compiled from the individual issues of the Official Gazette for the year. Under each case cited are given the points involved, a discussion, and the decision. There is a "Digest of Decisions" at the back. The discussions are often very informative as to the present state of the art. Patent Office practice is clearly exemplified by these concrete examples. The "Digest" is particularly useful as a subject index. (Note.—There is a "Decision Leaflet" which contains the decisions printed in each issue of the Official Gazette. It is obtainable from the Government Printing Office.)

"Manual of Classification of Patents:—1929," loose-leaf for the insertion of revisions which are occasionally made.

[1] With the exceptions noted, the books in this subdivision may be obtained from the Superintendent of Documents, Government Printing Office, Washington.

"This Manual is an instrument for use in searching classified United States patents. It comprises lists of classes, class and subclass schedules, and an alphabetical index of all class and subclass titles. The classification is designed to aid an investigator to locate a means of the useful arts when he knows its essential characteristics, whether or nòt he is familiar with the name or names by which it may be called. . . . The index is designed to enable anyone to locate the place in the classification of any means named in the subclass titles. The index is useful for search purposes only when the name by which the investigator knows any art or instrument is the name applied in the classification titles."

When using this manual one should also consult the "Definitions of Revised Classes" and the semiannual "Classification Bulletin."

The following three pamphlets may be obtained free by applying to the Commissioner of Patents, Washington:

"Patent Laws."

"Rules of Practice in the United States Patent Office."

"General Information concerning Patents."

Under authority of the Commissioner of Patents, at various times, indexes of foreign patents have been published. The following are typical:

"Subject-matter Index of Patents for Inventions (Brevets d'Invention) granted in France from 1791 to 1876," published in 1883.

"Subject-matter Index of Patents for Inventions (Attestati di privative industriali) granted in Italy from 1848 to May 1, 1882," published in 1885.

Great Britain[1]

The Official Journal (*Patents*) 1889– . Published weekly on Wednesday. Price £2 per annum. The word "Illustrated" was dropped in 1931.

[1] The books in this subdivision are published at the Patent Office; 25, Southampton Bldgs.; Chancery Lane, London, W.C. 2, England. "A complete list of the Patent Office publications can be obtained gratis on application."

"The Illustrated Abridgements of Specifications in Classes," 1855–1930. For 1865–1908, nine series of 146 vols. each: 1855–66, 1867–76, 1877–83, 1884–8, 1889–92, 1893–6, 1897–1900, 1901–4, 1905–8. For 1909–30, four series of 271 vols. each: 1909–15, 1916–20, 1921–5, 1926–30.

"Abridgment Class and Index Key," 3d ed., 1899, covers classification to 1908; 4th ed., 1910, covers the period 1909–1930 and the "Fifty Years Index."

"Fifty Years Subject Index," 1861–1910." Consists of 271 vols. based upon the 1910 classification scheme.

"Guide to the Search Department of the Patent Office Library." 4th ed., 1913 (Patent Office Library Series No. 4). Appendix I is "A Concordance to the Patent Classifications of England, Germany and the United States." The references cite many bibliographies of patents on special topics.

"Key to the Classifications of the Patent Specifications of France, Germany, Austria, Norway, Denmark, Sweden, and Switzerland," 3d ed., 1915.

"List of Patents in Force." Published annually. Grouping of the patent numbers is by years down to 1915. In that year consecutive numbering was adopted.

"Name Index." Vol. I covers the period 1617–1852. Thereafter one volume a year to 1888 when the index was made a part of the Official Journal.

Germany[1]

Patentblatt, 1877– . Published weekly on Thursday. Printed on one or both sides of the paper.

"Auszüge aus den Patentschriften." 1880– . Published weekly on Thursday.

"Verzeichnis der vom Reichspatentamt in Jahre —— erteilten Patente." Published annually for each year from 1877. Price varies. Some of the earlier volumes contain data for more than one year.

"Gruppeneinteilung der Patentklassen." 5th ed., 1932.

[1] Unless otherwise indicated, entries given here may be obtained from the Reichspatentamt, Berlin SW 61, Gitschiner Strasse 97–103, or from Carl Heymanns Verlag, Berlin W 8, Mauerstrasse 44.

"Stichwörterverzeichnis. Alphabetische Nachweisung technischer Gegenstande mit Angabe der Patentklassen und Gruppen." 4th ed., 1933.

"Gruppenliste der deutschen Patentschriften mit Angabe der zu jeder Klasse, Unterklasse und Gruppe gehörenden Nummern." 3d ed. 1928.

"Nummerliste der deutschen Patentschriften mit Angabe der Klassen, Unterklassen und Gruppen." 1928. Nachtrag 1929.

Jessop, E.N., *Ind.Eng.Chem.*, **8**, 1053–4 (1916). German Patent Bibliography. An excellent article on how to search the German patent literature.

France

Bulletin official de la propriété industrielle et commerciale. 2e partie: Brevets d'invention. Published weekly on Thursday by the French Patent Office (L'Office National de la Propriété Industrielle . . . , 31, Rue de Bourgogne, Paris VIIe. The Bulletin has for each "Brevet d'invention et certificat d'addition" arranged, according to class, the number, date, name of inventor, and title of the invention. (Note.—For patents numbered 317,502 to 385,891 write to M.M. Berlin, 8, rue Ferou, Paris, VIe.)

Austria

Oesterreichisches Patent Blatt. Published monthly on the fifteenth by the Oesterreichischen Patentamt, Wien I, Stubenring I. There are two sections. Part I contains patent news, new laws, and statistics. Part II has a list of applications and of patents granted. The classification is like the German.

Belgium

Recueil des brevets d'invention. Published by the Ministére de l'Industrie du Travail et de la Prévoyance Sociale, Service du Recueil des Brevets, 19, rue de la Loi, Brussels, Belgium. Part I of the Brevet is similar in appearance and content to our Official Gazette. The classification is essentially that of the French system.

Switzerland[1]

Patent-liste. Published twice a month by Eidg. Amt für geistiges Eigentum, Bern, Switzerland. Patents are classified according to a system like that of Germany.

NON-OFFICIAL LITERATURE

WORDEN, E.C., "Chemical Patents Index," Chemical Catalog Co., New York, 1927–33.

FRIEDLÄNDER, "Fortschritte der Teerfarbenfabrikation und verwandter Industriezweige," Julius Springer, Berlin, Vol. I to XVII. 1888–1932. The first 12 volumes, discussing patents issued from 1877 to 1916, were reprinted during 1920–22.

BRÄUER and D'ANS, "Fortschritte in der anorganisch-chemischen Industrie," Julius Springer, Berlin, 1921– . Four volumes, totaling 12 parts, describe the patents from 1877 to 1932. Volume I covers the first 40 years; the other 15 are divided equally between the remaining volumes.

HOUBEN, J., "Fortschritte der Heilstoffchemie, Erste Abteilung: Das deutsche Patentschriftwesen," Walter de Gruyter Co., Berlin, 1926– . Six volumes have been published covering the years 1877–1928: Vol. I, 1877–1900; II, 1901–07; III, 1908–12; IV, 1913–17; V, 1918–25; VI, 1926–8.

WINTHER, "Zusammenstellung der Patente auf dem Gebiete der organischen Chemie," A. Töpelmann, Giessen, 1908– .

WAGNER, "Jahresbericht über die Leistungen der chemischen Technologie." 1855– . Name varies. This work is divided into two parts, inorganic and organic. The "Patentregister" issued as a supplement to the Jahresbericht lists German patents in numerical order for 1878–1924. A second part covers the period 1925–34.

MISCELLANEOUS

ROSSMAN, "The Law of Patents for Chemists." (See above.) Chapter IX is good on searching the literature for prior publications.

[1] For a more complete list of countries and publications see: Smith, J.F., *Ind.Eng.Chem.*, **16**, 527 (1924). Patent Reference Sources.

UNTIEDT, F.H. *Ind.,Eng.Chem.*, **21**, 689 (1929). A short article describing the different types of chemical patent searches.

SMITH, J.F., *Chem.Met.Eng.*, **34**, 160 (1927). Patent Literature as a Source of Information.

EPHRAIM, J., *Angew.Chem.*, **39**, 1429 (1926). Patentability of intermediates.

MARX, C., *Chem.Age* (N.Y.), **31**, 398 (1923). Chemical patent searches.

BARROWS, F.E., *Chem.Met.Eng.*, **24**, 423, 477, 517 (1921). General data on chemical literature including patents. Also published as a thesis from Armour Institute, Chicago.

DANNERTH, F., *Chem.Met.Eng.*, **24**, 397–9 (1921). Legal and official chemistry.

EPHRAIM, J., *Angew.Chem.*, **31**, 241 (1918). Patentability of analytical methods.

HILL, E.A., *J.Am.Chem.Soc.*, **32**, 416–8 (1912). Describes the card index to chemical literature in the U.S. Patent Office.

GREGORY, "Serial Publications of Foreign Governments, 1815–1931," H.W. Wilson Co., New York, 1932. Gives official patent literature of various countries and indicates U.S. libraries having same.

BROWNE, C.A., *Ind.Eng.Chem.*, **18**, 884–92 (1926); HAMOR and BASS, *ibid.*, **23**, 10–14 (1931). Chronological tables of important events in the history of industry chemistry in America from 1557 to 1930. Cf. HAYNES, WILLIAMS, "Men, Money and Molecules," Doubleday, Doran & Co., Garden City, N.Y., 1936. On pp. 187–214, under the title "American Chemical Chronology," will be found a table covering the period 1608–1935.

GOVERNMENT PUBLICATIONS

"By a fiction as remarkable as any to be found in law, what has once been published, even though it be in the Russian language, is usually spoken of as 'known' and it is often forgotten that the rediscovery in the library may be a more difficult and uncertain process than the first discovery in the laboratory." LORD RAYLEIGH

A government publication is any book, pamphlet, circular, or map issued by, or at the request of, a public agency and supported by public funds. The form is immaterial. It may range from a bound report of a congressional investigating committee to a mimeographed sheet distributed by some city health department and may or may not carry the imprint of the Government Printing Office.

Sources

Depending upon the source, three major groups of government literature appear: federal publications, state documents, and official papers of lesser organizations, such as counties and cities. Within each group there can be subdivisions. The larger the unit the more likely they are to be present. Our federal government, being the largest entity, naturally is the most complicated and important. In fact, the Government Printing Office is the largest publishing house in the world. It issues over two million items each year. (Within the national organization the Department of Agriculture is responsible for the greatest number of publications.) State documents, while valuable in their various fields, do not include many of importance to the chemist. The same is true of the smaller geographical units. Attention will be devoted, therefore, only to national publications which, although most abundant in the fields of industry and technology, also contain a great deal on science.

Federal organization

Our federal government is divided into three branches: the legislative, executive, and judicial. Each of these is subdivided

again and again. The executive branch, under the direct supervision of the President, contains ten departments (State, Navy, Treasury, War, Interior, Agriculture, Justice, Commerce, Postoffice, and Labor), the Budget Bureau, and a number of independent institutions such as the Library of Congress, National Academy of Science, Smithsonian Institution, and Tariff Commission. Each one of these has its own internal structure, the whole conforming more or less closely to the following outline:

Executive branch
- Departments
  - Bureaus
    - Offices
      - Divisions
        - Sections
          - Boards
            - Commissions
              - Surveys
                - Services

Every one of these groups is potentially or actually the source of a report, bulletin, pamphlet, circular, or separate, perhaps a series of them. In addition, a number of the groups issue periodicals, e.g., the Bureau of Standards Journal of Research which appears monthly.

A more detailed discussion of the organization of our federal government would be out of place here, particularly in view of the fact that changes are frequently being made, so that what is true today may not be correct tomorrow. The essential point for anyone engaged in bibliographical work is that only by knowing about the various divisions, their duties and obligations, can a decision be reached as to whether or not anything of a chemical nature might issue from a particular source. It is necessary, also, to watch constantly for special commissions and their activities, especially the latter, because titles may reveal nothing.[1]

[1] The writer has at hand a copy of *House of Representatives Document No.* 1110 by the President's Commission on Economy and Efficiency issued in 1912. This book is a "Report of the Investigation of the United States Patent Office." It contains an excellent survey of the activities of that Office and includes under "Appendix K" a complete description of the "Index to Chemical Literature," a very valuable piece of work.

Once the type of work of any department is known, it is not difficult to watch for its publications. In many cases bibliographies are issued at intervals to all who request them. Frequently one can have his name put on the mailing list for "all literature" on a particular subject. This latter system, however, is not so common as it was a few years ago, because the present tendency is to abolish free distribution wherever possible.

Indexes

The Government Printing Office was established in 1861. Subsequently (1895) the Documents Office under the direction of the Superintendent of Documents was created and assigned the duty of acquiring copies of all publications not confidential and holding them for sale at a small fraction above the cost of printing. He was also given three other responsibilities involving the preparation of indexes to government publications. These are undoubtedly the most valuable guides to federal documents.

"Document Catalog," 1893– .

This is a comprehensive index of all documents specified in the printing act of Jan. 12, 1895—a straight dictionary catalog with authors, titles, and subjects all in one alphabetical list. The various governmental units are treated as authors. Titles are given exactly as as they appear on title pages. Explanatory notes regarding series, contents, etc., are included. While it is true that accuracy and completeness in such an index are time consuming, for a number of years the Catalog has been somewhat tardy in appearance. It is now available to June 30, 1933.

"Document Index," 1895– .

Frequently called the "Consolidated Index," this is a comprehensive list of congressional documents. It is issued for each session of Congress but is of little value to the chemist, not only because of the subject matter covered but also owing to the fact that only four libraries (Congressional, House, Senate, and Documents Office) receive the complete bound sets of the congressional series.

"Monthly Catalog," 1895– .

The full title is "Monthly Catalog, United States Public Documents (with prices)." Its purpose is to "show the documents printed during the preceding month, where obtainable and the price thereof." It is arranged alphabetically by issuing divisions, some[1] of which are:

- Agriculture Department
  - Chemistry and Soils Bureau
  - Food and Drug Administration
- Civil Service Commission
- Commerce Department
  - Census Bureau
  - Foreign and Domestic Commerce Bureau
  - National Bureau of Standards
  - Patent Office
- Court of Claims
- Court of Customs and Patent Appeals
- Interior Department
  - Geological Survey
  - Mines Bureau
- Smithsonian Institution
- War Department
  - Chemical Warfare Service

Mimeographed material and Patent Office specifications are not included. An index to the Catalog is issued annually. Until recently it was prepared for the period July 1 to June 30 but now covers the calendar year. Entries are by subject, series title, or individual title (if distinctive), issuing division, and personal author. The Catalog is free to public libraries. Individuals may subscribe for it at $1 a year.

In addition to the foregoing guides, the Documents Office also issues a "Weekly List of Selected United States Government Publications for Sale by the Superintendent of Documents." Each list is arranged alphabetically by subjects, with annotations and prices. There is also a number of "Price Lists" on special subjects, among them the following:

[1] This is only a partial list given to show the method of arrangement. To find material issued by the Bureau of Standards, first look for the heading "Commerce Department," then the subheading "National Bureau of Standards."

36. Government Periodicals
46. Agricultural Chemistry
55. U.S. National Museum . . . National Academy of Sciences. Smithsonian Institution
58. Mines. Mineral Resources . . .
62. Commerce and Manufacturing. Foreign Trade, Patents . . . Dyestuffs
70. Census Publications
75. Federal Specifications

These lists are sent free to all who apply for them.

Should the need arise to search the earlier federal literature the "Checklist of U.S. Public Documents, 1789–1909," will be helpful. The third edition[1] of this work, issued in 1911, is practically a shelf list of the public documents library in the office of the Superintendent of Documents. It covers 1,700 pages and comprises Vol. I of the Key. Volume II has not been issued. "For exactness and accuracy, admirable system, and completeness, it is a model of its kind . . . no other nation in the world . . . can show for its government publications anything to compare in excellence and value."[2]

Divisional guides

Turning to the departments and bureaus, a cursory search will reveal many guides to their publications—so many, in fact, that only a suggestive list can be attempted. Almost every publishing division issues, at intervals, catalogs of its own publications, which are complete or which show those available for distribution. A few examples are:

Agriculture Department

The Publications Division issues a "Monthly List of Publications." It also has several others, *e.g.*, Bulletin No. 6 covering titles from 1840 to 1902 and Miscellaneous Publication No. 9 for the period 1901–25. In 1929 it issued an index to Bulletins No. 1–1500. There are also volume indexes for each 25 bulletins beyond No. 250; cf. "Publications of the U.S. Department of Agriculture and How They Are Distributed," Circ. No. 6 (1922).

[1] A list of errors in this edition will be found in the *Monthly Catalog* for May, 1912, pp. 720–1.

[2] Italy may be considered a rival for this honor.

Commerce Department

The Publications Division issues a monthly and annual "List of Publications."

Geological Survey

There is a 221 page "List of Publications."

Mines Bureau

It issues a "Monthly List" covering: I, Sales Publications; II, Free Publications. In 1929 it published a "List of Publications, 1910–29" with a subject and author index.

National Research Council

Publishes a list of its bulletins, reprints, and circular series.

Smithsonian Institution

There is a classified list of publications available for distribution (cf. No. 2434).

Standards Bureau

Issues a monthly list of current publications. It also has published Circ. No. 24, "Publications of the Bureau of Standards, 1901–25," 7th ed., 1925, 271 pp. This has a subject index. There is a "Supplemental List, 1925–30," containing a subject and author index.

Acquisition

One of the serious difficulties encountered in the use of government documents is that the same subject matter may be issued in several different forms, e.g., as a "separate" unbound, as part of a bound annual report, as part of a bound or unbound special report. Consequently when any particular item is being sought the first thing to do is to secure as much information about it as possible, especially the date of issue, source or author, type of publication, and number. The Monthly Catalog gives directions for finding any document entered.

In general, there are three ways of securing national literature: directly from the bureau of issue; from a congressman; or from the Superintendent of Documents, Government Printing Office, Washington. The last source has nothing for free distribution except price lists; the other two frequently have a large quota of complimentary copies. Whenever a particular publication is no longer available from either of these agencies it may be

found at the nearest "Depository Library"[1] of which there are about five hundred. This source failing, the search should not be abandoned until the various forms (see p. 256) of publication have all been considered. Information concerning them can usually be obtained from the office of publication.

State Documents

"Monthly Check List of State Publications," Government Printing Office, Washington. In 1910 the Library of Congress began to issue a periodical record of new state documents currently received. All state publications, even legislative bills, press releases, and mimeographed issues, in so fár as available, are listed in full detail.

A number of individual states have prepared check lists of their publications, e.g., California, Minnesota, Wisconsin.

Foreign Documents

Gregory, "List of the Serial Publications of Foreign Governments," H.W. Wilson Co., New York, 1932. This is arranged alphabetically by country with subdivisions by departments. Material on Russia is in a separate section at the end. Like the "Union List of Serials" this book shows the holdings of each publication in some 85 United States libraries.

SHORT LIST OF GOVERNMENT PUBLICATIONS

The following brief list has been prepared to indicate the wide variety of publications issued by governmental divisions and to suggest likely sources for various data.

[1] A "Depository Library" is one to which, by law, the Superintendent of Documents must send all or certain publications of the national government. Each representative may select one library in his district, and each senator and delegate one in his state or territory. In addition, certain libraries have been designated by special acts. The libraries of all land-grant colleges are depository libraries. Apparently it was intended originally that depository libraries should receive all government publications. Later they were permitted to specify the types of documents to be sent. Thus we now have very few receiving everything published. Instead, there are special designations such as Geological Depositories and Patent Gazette Depositories.

Agricultural Chemistry	U.S.D.A. *Experiment Station Record.* A monthly publication covering the accomplishments of the various agricultural experiment stations. This will help to locate "Experiment Station" bulletins. U.S.D.A. *Journal of Agricultural Research.* (semi-monthly). Contains articles of interest chiefly to the biochemist.
Alcohol	Census Bureau, Current Industries Reports, "Acetate of Lime and Methanol." Appears monthly giving tables of production, shipments, and stocks.
Analysis	Mines Bureau, Bull. 212 (1923), "Analytical Methods for Certain Metals (Ce, Th, Mo, W, Ra, U, V, Ti, Zr). Hygienic Laboratory, Bull. 151 (1928). "Studies on Oxidation-reduction Nos. 1–10." The work of Clark, *et al.*
Babbitt	Census Bureau, "Babbitt Metal." A monthly report of consumption.
Bibliography	National Research Council, "Bibliography of Bibliographies on Chemistry and Chemical Technology," by West and Berolzheimer. Bull. 50 (1925), 71 (1929), 86 (1932).
	Smithsonian Miscellaneous Collection, "Select Bibliography of Chemistry," by H.C. Bolton. Vol. I, No. 850 (1893), covers the period 1492–1892 and includes Bibliography, Dictionaries, and Tables, History of Chemistry, Biography, Chemistry Pure and Applied, Alchemy, and Periodicals. The first supplement, No. 1170 (1899), covers the period 1492–1897; No. 1253 (1901) includes only "Academic Dissertations, 1492–1897." The second supplement, No. 1440 (1904), covers all eight sections for the period 1492–1902. This is a very valuable guide to the earlier literature.
Business	Foreign and Domestic Commerce Bureau, *Survey of Current Business.* Appears monthly. There is a weekly supplement.
	Idem., Chemicals Division, *World Trade Notes on Chemicals and Allied Products.* (Weekly).
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Helium	Mines Bureau, Information Circ., I.C. 6745 (September, 1933) "Helium."
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Paint	Census Bureau, Current Industries Reports, "Paint and Varnishes." Semiannual publication.
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Standards	Standards Bureau, Miscellaneous Publications, M130 (1932), "National Directory of Commodity Specifications."
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	Idem, M110 (1930), "Standards and Specifications for Non-metallic Minerals."
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Statistics	Census Bureau, "Census of Manufacture." Issues printed pamphlets on the more important industries. These appear not later than July of the year following the census.
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Steel	Mines Bureau, Reports of Investigations, R.I. 3205 (May, 1933) "Development of an Electrolytic Method for the Determination of Inclusions in Plain Carbon Steel."
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LITERATE REPORTS

"It is surely consonant with the chemist's sense of accuracy that his writing should be exact, and with his sense of form that it should be subject to agreed rule and order. His pen is for the moment part of his scientific equipment, and to use it injudiciously is no more excusable than to lack skill in the manipulation of his other apparatus." ANON.

The chemist is essentially a bench worker, but gathering results is only part of his business. He must also keep intelligible laboratory records and, from time to time, give oral or written reports of his progress. The published accounts of his results have been discussed in earlier chapters of this text, but nothing has been said about the preparation of such records. Consequently, this final section will be devoted to some of the various types of technical reports and the aids available for their composition.

Notebooks

The most important and occasionally the most neglected part of an experiment is the laboratory record. It frequently becomes the only tangible product of an extensive investigation, the only source of information for later experiments, or the essential evidence of diligence and priority in some patent litigation. Consequently, to anticipate any future need all research notes should meet the following minimum requirements:[1]

1. Records should be kept in a notebook, not on scraps of paper. The pages should be consecutively numbered.
2. Entries should be (*a*) in ink or indelible pencil, (*b*) unmistakably identified, (*c*) dated, and (*d*) witnessed if sufficiently important.[2]
3. When work is begun on a project the first entry should be a statement of the problem and proposed mode of attack.

[1] For references, see p. 267.

[2] The court will not accept an investigator's statement without verification.

4. Sketches should be made of important apparatus showing essential parts, connections, and relative size or capacity of the elements.

5. All operating details and variations should be mentioned: reagents, temperatures, pressures, time required, yields, etc. These data should be complete and not entrusted to the memory of the operator.

6. All calculations, observations, and conclusions should be fully recorded. The apparently trivial factor in one experiment may be very important in another.

7. Results should be explained, in spite of the oft heard statement that figures speak for themselves.

Oral reports

The active chemist must expect to discuss his work with his employer and to give papers occasionally at the meetings of colleagues. Success is this field demands a knowledge of public speaking—the importance of an adequate introductory orientation of one's audience, how to present data effectively, and when to stop talking. A large number of books has been written on this subject. Directions for finding them have already been given, but even a cursory discussion of their merits is beyond the scope of this text.

Written reports

The purpose of any report will determine its form and content. If written for publication, typical articles in the journal concerned and suggestions by the editor should be studied. The general arrangement of subject matter and other stylistic details should be followed.

Reports for a chief chemist or other official of an organization are usually prepared according to directions supplied by him. If they are lacking the following hints may be useful.

Progress report

When a research project is undertaken, preliminary or progress reports are expected at regular intervals. The purpose of these records is to give a concise and accurate account of what has been accomplished, how it has been done, and what remains to be

finished at any particular stage of the work. Each report will begin with a summary of the results, then give the status of the problem at the time of writing, and end with an outline of the experiments planned. If the preceding parts have been well written the last will require no justification. Two important features of the report are an adequate introductory sentence or paragraph and a discussion of the significance of the results. The report should be typewritten on standard $8\frac{1}{2} \times 11$ inch paper, dated, signed, and attached to a letter of transmittal.

Final report

At the end of an investigation a final report should be prepared covering all phases of the work. The first division should be a brief summary of the study and the conclusions warranted. This may be followed by a detailed statement of the problem, previous investigations, method of attack, apparatus used (with sketch or pictures), results obtained (graphically shown if feasible), observations made, and conclusions. Other details should be the same as those in a progress report.

Method of analysis

If sufficiently important the results of a chemical analysis should be accompanied by a report covering the following points in the order given: object, results, details. The last division should reveal the source and identification of the samples, method of sampling, analytical procedure, probable accuracy of the results, bibliography (cf. References, p. 276).

Method of preparation

When asked to search the literature for a method of preparation without thought of commercial exploitation, the chemist's report on the selected procedure should cover:

a. Exact reference to the original article, especially the author and year of publication.

b. Method:

Reagents, conditions, time, and apparatus required.

c. Yield:

Quantity and quality.

Commercial venture

The beginning and the end of every commercial venture is a marketing problem the final answer to which must be a positive number if the company expects to remain in business. Consequently, the preliminary library and laboratory study of any product not previously manufactured by an organization must take into consideration:

a. The method and its patent status.

b. Raw materials:

Location, cost, quality, availability.

c. Manufacture:

Location of plant, working conditions, equipment, steps, costs (heat, power, and labor), yield, purity, by-products and their possibilities, competitive advantages.

d. Market:

Probable demand, stability, location, quality required, price fluctuations, sales units (ounce, pound, ton), competition.

Composition

Only a few general suggestions will be made here concerning the question of composition, but there should be no doubt in the mind of any student regarding the importance of this topic. Daily the demand grows more insistant for investigators who can write reports that are accurate, easy to read, and readily understood.

The object in technical writing is to "convey information not to confound the reader." The primary requisites are a good foundation in grammar, an ability to spell, and some notion of punctuation.[1] Short sentences and short words are essential to a simple, clear, and concise style. It is easy to place words on a line, but to write well requires practice. No practice is effective without guidance.

A title should be brief and should accurately describe the contents of the article. Sentences must be grammatically

[1] As a simple example note the importance of the hyphen in the following: forty one-inch tubes, forty-one inch tubes, forty-one-inch tubes.

correct, properly punctuated, and free from unnecessary words.[1] Paragraphs must have unity and coherence. Although there are disagreements as to style the chemist should choose an authority in good repute and follow his decisions. Results can be presented graphically or in tabular form. There are rules covering each method. For illustrations line drawings are frequently more satisfactory than photographs.

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[1] *The hot solution is poured* is better than *The solution is heated and then poured.*

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COMPILING A BIBLIOGRAPHY

The facts in a report are based upon personal experience and information gleaned from the literature. Of course all help should be acknowledged. In addition, contradictory as well as favorable evidence should be indicated. The references may be scattered throughout the text, placed as footnotes, or gathered in a list at the end of the article. In either case, the group of citations is called a "bibliography" even though no books are included. This apparent misuse of the term is sanctioned because the greater part of scientific information is now published in journals. The accepted working definition of a bibliography is, therefore, a (classified) list of authorities on any theme.

Purpose

It is not to be inferred that a bibliography is compiled solely to accompany a report. Many are published independently, and a much larger number is assembled for personal use. In the latter case, if a specific research problem is involved, some investigators question the wisdom of consulting the literature before the preliminary experimental work has been finished, because reports of failure by others might result in abandonment of the idea without a trial. Another group believes that a personal file of data represents time wasted, because a good abstract journal is a better bibliography than any individual can prepare. Regardless of opinions respecting these points there is no question about the necessity for compiling bibliographies (*a*) to secure a composite viewpoint, (*b*) to reveal problems for investigation, (*c*) to aid in directing research through knowledge of what has been done, (*d*) to obtain suggestions regarding technique, (*e*) to disclose the state of the art, (*f*) to support or oppose a belief, or (*g*) to avoid controversy.

Essentials

A bibliography must be full, accurate, consistent, adequate, and well arranged. A full list is one that contains all pertinent references of importance. The narrower the subject the greater

the effort should be to secure completeness. To insure accuracy or exactness, it is necessary to verify each reference and effectually identify every source. Consistency demands a standard style which shall be the same throughout the list for references of the same kind. Adequacy involves two factors: time and subject matter. In careful work, where priority is involved, not only the year but also the date received and date published should accompany an article reference; for patents the date of application and the date granted are required. Entries should not be made with the expectation of returning to the source at a later date. All essential points should be recorded at one time. In an extensive list the arrangement must help the searcher to find any desired reference. Finally, there should be no illusion about any bibliography; in reality, it is never finished and is always more or less defective. This may be interpreted as a challenge to the compiler and as a note of caution to the user.

Scope

The scope of a bibliography is largely dependent upon its purpose, the ability of the searcher, and the library facilities. A complete list is usually the work of years. A partial roll may be limited as to subject, time, language, country, and type of publication (book, pamphlet, article, patent, public document, etc.).

Equipment

Large industrial corporations usually have forms to be filled out and filed according to a definite scheme. When the chemist plans his own system he must select the equipment. A loose-leaf binder[1] is useful for short investigations, but for longer studies or a permanent record the addition of index tabs, envelopes, or file pockets will be necessary. Heavy manila envelopes are particularly suitable because there is ample space on the outside for contents notes, and the paper will withstand considerable handling. File pockets, plus a cabinet, make an excellent repository but are more expensive. If the collection is not to be moved frequently the use of card-index cards is generally most satisfactory. The size should be standard, 3×5, 4×6, or

[1] Many chemists use the Lefax system.

5 × 8 inches, depending upon the amount of space required. The cards should not be too thin or too heavy; about 40-pound stock is preferred by many people, although material twice that weight is occasionally desired. Good bond writing paper is suitable for the larger sizes of cards. The paper must be cut, not torn, to the right dimensions. Printed forms are useful but not essential; Fig. 4 indicates a possible arrangement. Finally, the color and cut of guide cards require some considera-

Subject____________________ Class__________

Author______________________________

Title______________________________

Original Journal__________ Vol._____ pp._____ year_____

Abstract Journal__________ Vol._____ pp._____ year_____

Summary.

FIG. 4.—Form for printed index cards.

tion. One scheme employs pink cards, cut two[1] for main headings; and yellow cards, cut five for subheadings.

No system should be hastily adopted. Acquaintance with the possibilities, a little consideration of future needs, and sensible planning will help to establish a system of real value and avoid an exasperating confusion of miscellaneous forms.

Style

If a bibliography is compiled for publication in a specific journal, at the beginning the style employed in current issues of that journal should be adopted with respect to placement, order, and abbreviations. This eliminates subsequent editing and

[1] This means that the tab at the top occupies one-half of the length of the card.

time wasted in re-searching for data that could have been obtained during the initial reading of the sources.

When the writer is free to adopt his own style he should not put references in the text as hurdles for his readers. A list at the end of the article is more desirable if adequately keyed to the text.

As previously stated, citations must completely identify the original publication. In addition there may be a summarizing annotation or a direct quotation of the statement involved. For a personal collection the entries and order suggested in Fig. 4 are deemed suitable. Book references will include the publisher, his location, the edition, and date in place of the "Original Journal" entry.

Compilation

The method of procedure should be systematic, logical, and orderly. After a subject has been selected, if nothing is known about it there is, perhaps, no better way to begin than by carefully reading the most comprehensive work on the topic.[1] An outline, as detailed as possible, of the main divisions and subdivisions of the field can then be prepared to serve as a list of search headings and for the orderly filing of data. Next, make a rapid survey of the literature to disclose an up-to-date bibliography or to reveal an old one that can be quickly expanded to meet the needs of the problem. For such examinations, start with a bibliography of bibliographies. Later, if necessary, inspect the following in the order mentioned: encyclopedias, annual reports, reviews, indexes of abstract journals. If no bibliography is found, prepare from the outline a detailed, alphabetical list of search headings, including synonyms, antonyms, related subjects, and more general topics. Also make a roll of the active workers in the field as soon as possible. Then search the latest annual index of Chemical Abstracts or the Zentralblatt for each author and subject heading. Whenever one of these is found, note the accompanying page number. When the end of the index has been reached, the recorded page numbers should

[1] It is a waste of time to start compiling a bibliography on an indefinite subject because there will not be adequate criteria for including or excluding any material.

be in numerical order on one card or sheet. Lay this aside and scan the next preceding index. As soon as the cumulated indexes are encountered, the annual volumes may be disregarded,[1] but the use of a different card for each year of the journal should be continued.

The indexes having been examined, arrange the cards in volume number order and scan each page for the abstract cited in the index. If the abstract indicates that the original article contains pertinent data an index card (Fig. 4) is filled out except for the summary.

After all abstracts cited have been considered arrange the index cards in a "finding order," grouping the references to each journal separately and chronologically. Read each journal article and summarize it on the proper card, organizing the notes in a definite order. If desired, a photostat or filmstat copy of the article, or any portion, can be made a part of the record.

Finally, it is understood that some system of checking will be adopted to insure completeness. For example, one abstract journal should be compared with another, and in the case of book titles the United States Catalog and corresponding foreign publications must be searched. Ultimately a stage is reached when almost all of the literature will have been examined. To secure the remainder may be very difficult and perhaps not worth the extra effort.

Arrangement

A short bibliography of twenty to fifty entries may be arranged alphabetically by authors, chronologically according to date of publication, or in the order in which the authorities are mentioned in the article. For reference guides, connecting subject matter with authority, a number of devices are in use: (*a*) small, superior numerals or letters; (*b*) parenthetic numbers or letters on the text line; (*c*) author's name, with or without the date of his publication, in parenthesis after the citation; etc.

An extensive collection of references will be of little value if authors' names form the only key to its contents. In spite of the fact that this is the commonest system it is generally the least useful. A chronological order is almost as unsatisfactory,

[1] This system may be reversed, of course.

although it does emphasize the historical development of the subject. Title, or regional or source arrangements are seldom encountered in chemical literature. One is almost forced, therefore, to adopt a subject classification because it is the most effective and economical. Since efficient indexing is an absolute necessity careful attention must be given to that phase of the scheme. Depending upon the complexity of the problem, some of the following procedures may be of service, for it is always easier to adapt a tested method than to create one.

One of the best known systems for the arrangement of notes, clippings, etc., is the Dewey Decimal Classification. As it stands, however, it is not sufficiently detailed for the chemist. Consequently, the Brussels, or International, expansion is more useful. According to the latter scheme, a subject heading is selected for each item to be filed. This heading is then found in the "Relativ Index" or outline, and the number assigned there is placed on the item, thus giving it a location in the collection. The difficulty with this method is that usually more than one subject heading will be applicable. For a public collection it may be advisable to enter a copy under each one, but for a private compilation the best heading should be selected, and cross reference cards used for the others.

Another method is to follow the subject-index arrangement of Chemical Abstracts. This has the same impediment mentioned in the preceding paragraph. The Zentralblatt uses a subject classification plus alphabetical grouping within each subdivision. The "Reader's Guide to Periodical Literature" follows the same plan and also includes author entries. It should be noted that there are two possibilities with each one of the three systems: (*a*) The items may be filed in the order of appearance of the entries in the index, or (*b*) they may be numbered and filed consecutively to be located when needed by means of a guide. Of course a card file must be used for the index to permit the insertion of entries wherever necessary.

A filing system recommended by McClung and McCoy requires a set of master and of subject cards. Each master card has on it a complete summary of one article, book, or patent and is filed alphabetically by author. A subject card is prepared for every subject on each master card. The subject card has

only a heading and the author's name. When filed alphabetically according to the heading the card becomes the key to the master card on which the subject is discussed. The scheme is simple and eliminates considerable duplication. It may be improved by the judicious use of red ink on the master cards.

When the data are all in one division of chemistry a very good scheme is to use a comprehensive textbook in that field as a key. In qualitative analysis a copy of McAlpine and Soule's "Qualitative Chemical Analysis" may be employed. Each entry of the file is arranged in the same order as the subject is discussed in the text and coded with the page number on which the subject appears. The index of the book will then show where to find any card, since the page number in the index and the card number in the file are identical. If the bibliography is confined to one element the classification in Gmelin's "Handbuch" may be useful. Richter's "Lexikon" can be utilized for organic compounds, Hoffmann's "Lexikon" for inorganic, and data on dyes may be keyed to Rowe's "Colour Index" or Schultz's "Farbstoff-tabellen." Other books will also be found useful for this method. It makes little difference which one is chosen if the cards in the file can be quickly located when needed.

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INDEX

This is a combined subject, title, and author index. While it is considered a reasonably detailed inventory of the text, no attempt has been made to enter each item under all possible headings. Many of the subject entries will reveal only references to sources of information since the text is a guide to, not a compendium of, the chemical literature. Book titles are usually entered in two ways, viz., under the first word not an article, and in an inverted order to make them appear under the word that a chemist would probably seek first. Thus a book entitled "A Modern Approach to Inorganic Chemistry" would be entered under "Modern" and also "Inorganic Chemistry, Modern."

Journal titles will be found in the places where they would appear if spelled out but the actual entry is the abbreviation used by Chemical Abstracts.

Author entries carry forenames or initials wherever the surname alone does not identify the individual. Forenames of joint authors, however, have frequently been omitted since there is no risk of confusion.

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THE MAPLE PRESS COMPANY, YORK, PA.

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Similarly other conversations with men in business, men who have heard of chemists, but who really have not much of an idea as to how they work or what they can accomplish, have made it seem that some of this group too might be interested in learning something about the kind of help they could expect to get from chemically trained people.

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unfamiliar with that work a quick look at the subject, the following pages have been prepared. If to some readers the presentation seems at times to be a rather flippant handling of material usually treated seriously, it should be said that there is a defense to be offered. Laymen are apt to regard us as an uncompromisingly serious-minded lot and unfortunately when they have decided that about us, it is sometimes hard to get them to accept us as members-in-good-standing of a business organization. There seemed to be some point in reminding ourselves, and perhaps others as well, that after all, chemists are people too.

HERBERT COITH.

WYOMING, OHIO,
May, 1943.

CONTENTS

FOREWORD

Dr. Coith is a shy author. I had worked with him through a hot Washington summer in an improvised office which reverberated with perpetual conferences and shouted telephone conversations, but he had given no inkling of an instinct for authorship, save for that afternoon when he worked three hours trying to redraft a WPB legal order so that it could be understood.

It took Mrs. Coith's initiative to produce "the manuscript" one evening—the manuscript which Herb had labored on spasmodically over many years. And as I became absorbed in chapter after chapter, each with its introductory ballad, its direct approach and its apt examples, embarrassment flushed his face with my every comment.

This book is intensely practical. It is written by a man who glories in being a chemist, and who has a broad concept of the chemist's responsi-

bilities to his fellow men and to society. Its values may be greatest to the young chemist and chemical engineer in his twenties—in the years of graduation from school and introduction to industry. It is definitely not a sales appeal for the youngster to pick a chemist's career. Rather, it is an honest and perspicuous analysis of the varied professional functions and responsibilities of the chemist, of the importance of his jobs, and of the characteristics which are required to perform them.

Older men will relish the mature philosophy of the author, and will conjure illustrations from their own experiences to parallel those which Dr. Coith presents. The young college student may sometimes be bewildered because his practical world is not what he had imagined. But all can profit from the lucid exposition of the chemist's professional life and of his opportunities for service.

WALTER G. WHITMAN.

WASHINGTON, D.C.,
May, 1943.

SO YOU WANT TO BE A CHEMIST?

Chapter I

WHAT IS A CHEMIST?

We're a wondrous big division of a prosperous company.
We're the chemists.
Bum! Bum!*
We're the chemists.
We consist of a director and a young washboy and me
And other chemists.
Bum! Bum!
And other chemists.
Some cynical folks around the place just wonder what we do,
And frankly, there are days, b'gosh, when some of us wonder, too,
But we'll show the dirty doubters something new before we're through.
We're the chemists.
Bum! Bum!
We're the chemists.

But what is a chemist? Yes, what?

And immediately someone raises a counter-question, perhaps after the manner once made widely famous by a couple of well-known gentlemen of color:

* Words inserted to round out the rhythm, not adjectives referring to chemists.

"What's yo'h idea in bringin' that up?"

Well, there are several ideas. In the first place, and purely from a selfish angle, it would be nice if it were possible to give the layman a notion of what chemists do, so that when we admit that we are chemists, they would not reply with that inspired question, "Oh, so you work in a drugstore, do you?"

Something also would be gained if people in general got enough of an idea of the difference between a chemist and a soothsayer so that Cousin Elmer or Old Man Dowie or someone else would not continually be bringing us a little bottle of this or a can of that or a hunk of the other to examine, open the conversation with that flattering challenge, "Say, you're a chemist. What's this made of?" and then stand by expectantly, waiting for us to take a look or a sniff or a taste and give a formula for reproducing the stuff.

In the next place, maybe it would be interesting to the thousands of students in schools scattered about the country who are preparing themselves for chemical careers to know something about whither they are bound and what sort of work

awaits them when they face the world. Do the pretty pictures in the magazine advertisements—those showing learned-looking sages with pointed beards and nice white jackets like the ones dentists and soda-fountain clerks slip on when they go to work—really represent a chemist or not? Will they, the aspiring students, some day be peering into a beaker or a test tube just as those boys in the pictures do, with a microscope at one elbow, a Bunsen burner at the other, and an artistic, if not realistic, blown-glass thingumajig in the offing ready for the next experiment?

Or those other pictures which occasionally appear in the magazines, showing just the kind, honest face of the "chemist" who thinks so-and-so about some tooth paste or cosmetic, in much the same way as a movie queen hails a certain lipstick or cigarette or as the Duchess of Bilgewater eulogizes something dainty in brass beds—do they show the chemist in his ultimate transcendent development?

If pictures of the first sort, the chemist practicing his trade, do not truly reflect how chemists work, and if pictures of the second sort, just the

calm face of the scientist in repose, do not show what the chemist may hope some day to become, then what sort of future does await these students when they finally turn their backs on campus life and start out to demonstrate that the money father spent on their higher education was not entirely wasted?

In the last place (and pay very close attention now, you brothers in chemistry), if we could only get across to more of the country's business leaders a little better idea as to just what chemists *can* do, so that they would realize how much more service they could get from chemically trained men than they are getting, they would be putting us in places of greater responsibility, the demands for our services would increase, and, b'gracious, by and by we would all be getting higher salaries. Verily, a consummation devoutly to be wished, if ever there was one.

With these assorted noble aims we move on to the attack. What is a chemist?

But hold a moment! As a humble scientist turned even more humble by trying to be an author, the writer realizes that anyone attempting

to answer the question under discussion is on his way to controversy because there are so many points of view from which to approach the subject.

No one will expect the typical, deep-dyed researcher who puffs his pipe and ponders over the possible action of nitrosodimethyl-so-and-so on apiole to look at the matter in quite the same way as does the young college graduate-assistant, much of whose energy is sapped in worrying over whether the blasted freshmen will ever learn the gas laws. And neither of them will have quite the same slant as that of the vice-president in charge of production who has agreed to a half-million-dollar chemical-division budget for the fiscal year and who thereafter keeps a slightly flinty weather eye out to see what his company is going to get for the money.

Under the circumstances how easy it would be to fool someone into reading the pages which are to come, without his fully realizing where he was being led, and then have him find out in the end that he had been tricked into investing his time in reading rubbish. Such a thing would never do, and it shall not be!

In order that it may be clear to all you readers, before you wade through many more pages, just what you are in for, we shall set down in the next few paragraphs a brief résumé of what is coming. Take heed! The remainder of this chapter is here for your protection and if, after you have completed it, you *will* read on, don't say you were not warned. You will have gone into it deliberately.

To begin with, let it be known that we propose to discuss the work of the chemist in industry. Because such work is so varied and leads into so many unexpected directions, the field becomes an extremely broad one. Therefore our first task is one of dividing that broad field into a few simpler subdivisions which we can consider individually and which we can then put together and study as a whole.

There are various ways in which the subdividing might be done, and we make no claim that the way we are going to adopt is better than any one of a number of others. But for our present purposes let us consider the work of the industrial chemist as it relates to:

Raw materials
Processes
Finished products

Then, having established the foregoing fields, let us introduce a second set of divisions as follows:

Standards
Laboratory investigation
Plant investigation

And now, having made two simple divisions, let us combine them in a sort of a table, this way:

	Standards	Laboratory investigation	Plant investigation
Raw materials	X	X	X
Processes	X	X	X
Finished products	X	O	O

You will note that under the column headed Standards we have put three X's. These are intended to signify that the chemist in industry is going to concern himself, among other things, with standards for raw materials, standards for processes, and standards for finished products.

Again, there are X's in our chart intended to convey the idea that both laboratory and plant investigations are to be carried out on raw materials and on processes.

When we come to products, however, both under Laboratory investigation and under Plant investigation, we find not X's, but O's. These are not intended to indicate that laboratory and plant studies are not to be carried out on finished products, but to focus our attention for a moment on the fact that much of the investigational work carried out on products is done from a point of view quite different from that done in connection with raw materials and processes. Specifically, the difference referred to is this:

We investigate our raw materials and our processes from our own standpoint or, rather, our company's standpoint. We want to find substitute raw materials, develop improved processes in order to increase our yields or simplify our operations—to lower our costs, to save money. But we investigate our finished products not only from our own point of view, but from the point of view of our customers as well. We want to

develop new products that will be more serviceable to the people who buy our goods, or we want to find better ways for customers to use our present products. To be sure, in the last analysis, these objectives too take account of our point of view because we hope, by making such a study, to lead our customers to feel that they want to buy our products instead of those of some competitor. Nevertheless, there is a distinction that we believe justifies giving separate consideration to certain kinds of investigational work on products. In order to have a convenient name for work in which the customer's point of view is given particular attention, we are going to call it "products service."

Now there are, as we have shown in our tabulation, two types of investigational work: that carried on in the laboratory, and that done in the plant. In order that we may have convenient names for these we are going to designate laboratory investigational work as "research" and plant investigational work as "plant development."

Summing up our discussion to this point, we find we have divided the work of the chemist in

industry into four fields, and the worker in each of these fields concerns himself, though from different points of view, with raw materials, processes, and finished products. We therefore revise our previous chart and construct the following one, which designates the field of work in which the industrial chemist occupies himself.

	Standards	Research	Plant development	Products service
Raw materials	X	X	X	X
Processes	X	X	X	X
Finished products	X	X	X	X

In large organizations a whole group of workers may be engaged in each field. In a small company a single chemist may be undertaking to cover all four. But in any case the chart shows the range of activity that has to be considered. Our next step will be to discuss the divisions individually.

Chapter II

STANDARDS

Some analyze the samples that are brought in by the bunch.
Weary chemists.
Bum! Bum!
Weary chemists.
And others grade the garbage grease, then sit near us at lunch.
Smeary chemists.
Bum! Bum!
Smeary chemists.
And some set specifications telling our buyers what to buy,
While others write "Factory Standards" telling what to do and why.
They help the superintendents out, or anyhow they try.
We're the chemists.
Bum! Bum!
We're the chemists.

We start by taking up the work of the standards department because this work is probably the most obvious and most commonly practiced work of the chemist in industry, and, as such, it will be somewhat more familiar to a greater number of readers than would any of the other

divisions with which we might begin. Again, an understanding of standards work will give us the best possible foundation for discussing the subjects that we want to develop later. It will help us get our feet on the ground because it deals, for the most part, with things as they are. When we come to research, plant development, and products service, we are going to be considering mainly changes—substitute raw materials, alternate processes, or improved finished products. But standards are set to guide and control operations as they are currently being carried out.

For that reason, incidentally, a man starting his first job with a concern can look to the standards department to obtain information necessary for orientation in his new work.

There is not much mystery in the work of a standards department. Its primary function is to ensure uniformity of finished products, and, because uniformity in these cannot be controlled efficiently without uniformity of processes and uniformity of raw materials, standards and specifications are established and maintained for all these.

But it is not enough simply to set standards. Instructions for meeting and maintaining these standards have to be given to the persons or departments concerned, and, since such instructions are usually quite involved and include many important details, it becomes necessary to set them down in writing. Thus the standards department becomes a compiler of specifications for purchasing agents, an author of instruction books for plant operators, and a recorder of necessary qualities in finished products.

Setting the standards and writing and distributing the information concerning them, however, does not represent the whole extent of the standards department's job. In fact, it is scarcely the beginning. The real job comes in exercising a constant vigilance over materials, processes, and products to see that the proper quality is maintained. Call it checking, auditing, policing, anything you like, the job remains the same and its watchword, aimed at products that are in any way substandard is this: They shall not pass!

With such an objective before it, the standards department prescribes tests that shall be made on

materials going into a process, materials at various points during the process, and materials as they emerge from the process, to assure everyone concerned that all is well.

But these tests—where are they made, and how? They are made in the testing laboratory by the application of analytical chemistry.

Here, in a sense, we have come to the real beginning of our story, for analytical chemistry, using the term in its broadest meaning, is the cornerstone of all chemistry. It is the fundamental, the *sine qua non* (which I just looked up in the dictionary and which, according to that comprehensive volume, means "that which is absolutely indispensable"). It is the essential tool without which the handicraft of the chemist cannot proceed. It is chemistry's measuring stick.

At this juncture some of our hairsplitting contemporaries, who insist on words being used in their exact meaning, will point out that we are taking in an unjustifiably large territory for analytical chemistry. They will quote our friend the dictionary to the effect that analysis means "ascertaining or separating the elements of a complex

body," and that there is a lot of measuring done in chemistry that does not fit in with that definition. Of course, strictly speaking, they are right. The analysis of a piece of alloy, in which we determine the percentage of the various metals which it contains, lines up with their definition perfectly, but the "analysis" of an oil in which we determine such things as iodine value, saponification number, refractive index, and perhaps various other characteristics, does not meet the ironclad definition of analysis at all. Yet by custom we have come to regard many measurements of physical and chemical properties as belonging in the same general realm as "ascertaining the elements of a complex body" and we have put the whole lot together into that division of our science which we call "analytical chemistry."

In spite of the fact that analytical chemistry is a vital factor in every chemist's every undertaking, it is regarded by some of our scientific coworkers as a matter of minor importance. Occasionally men are unwilling to admit before a group of their fellow scientists that they are connected with analytical chemistry because that seems, in certain

quarters, to stamp them as low grade. Now why is that?

Well, the reason no doubt is that in numerous industries where chemical control is practiced the routine analytical work is carried on by boys who have no chemical background but who have been taught a certain series of manipulations, just as you or I might be taught to tat, knit, or crochet, provided someone could be found with patience enough to teach us. In their environment these laboratory boys are sometimes alluded to as "chemists" so the impression gets abroad, and takes root in the minds of some people who ought to know better, that that is what they are.

We ought to pause for a moment at this point to cry out against those manufacturers who have hired someone to do routine testing for them and thereafter labor along under the delusion that their concern has a chemist. There are all too many companies like that, and the lamentable fact is that such companies don't even know what a chemist is.

Of course, it is true that in smaller concerns a chemist may have to do his own testing, and we do not for a moment mean to suggest that, when

such a condition exists, the work is unworthy of him. On the contrary, we should like to stress the point that no one engaged in chemical activity can afford to take the attitude that a real chemist is above having to think about analytical work. However, performing routine analyses should not be mistaken by anyone as the objective toward which chemists strive. If an organization has a place worth putting a real chemist in, it will probably be worth while to give him a laboratory helper to relieve him of details that require a willing pair of hands but not a chemically trained head.

The foregoing paragraph brings to mind a piece of work done under the supervision of a man whose well-known name brings thoughts of achievement to the minds of those who hear it, but who has unburdened himself from time to time regarding the status (or rather, lack of status) of analytical chemistry. The piece of work referred to required several months for completion and represented an appreciable outlay in time and money. It had to do with learning what happened to a substance during a certain process. The material going into the process was analyzed, as were

the products and by-products coming out; all this for the purpose of determining how much of the substance went into the product, where it was wanted, and how much into the by-product, where it was not wanted. Further, it would presumably be found how the process might be varied to put more of the substance in its proper place, that is, in the product. But alas! After all the outlay of time and money the results were a meaningless hodgepodge. They didn't fit and the accounts didn't balance, so to speak. Notwithstanding this unfortunate lack of consistency, a voluminous and solemn-looking report, which tried to account for the discrepancies, was submitted to the organization that had paid to have the work done. After the report had been received and wondered about a little, some lowly chemist in the organization, who had an interest in analytical procedure, dug into the analytical methods that had been used. He found that, at one point in the vital analysis on which all the work rested, there was supposed to be added a certain reagent, part of which reagent was supposed to combine with the substance being deter-

mined, and the remainder of which, or excess of which, was to be measured by suitable means. From the data thus obtained it was to have been possible to solve the problem. In the work as actually carried out no excess had been used. In fact, only 10 *to* 40 *per cent* of the amount necessary to combine with the substance in question had been used, to say nothing of an excess. As a result, the analyses were all "off" and the entire job was worthless.

Obviously impossible, you think. No reputable consulting chemist could be caught in such a situation. Well, believe it or not, as the cartoon man would say, this thing actually happened. This great and good man, who holds firm to a lofty belief that analytical chemistry is something to be handled by the less capable, permitted money to be spent and human energy to be squandered on a project just because he didn't make sure the fundamental analytical procedure was what it should be.

Analytical chemistry may become routine, and frequently does, but never can anyone safely take for granted that it is not worth intelligent attention.

It is really shameful the way we have run away from the subject of standards, which is what the present chapter originally set out to be about, but as long as we have gone into this matter of analysis as far as we have, we might go just a little further and consider for a moment the possibilities that analytical chemistry offers to men going into industry. If it is so all-important as we indicated a moment ago, perhaps it offers excellent chances. Perhaps! As a matter of fact, however, it does not.

There are some analytical jobs in the research departments of large companies which are not routine, which afford many interesting analytical problems, and which may lead to a fairly good, though never large, salary. But permanent jobs in analytical control work can never be looked upon as very desirable from the point of view of the trained chemist.

In spite of the rather discouraging outlook that control analysis offers, a certain amount of it is very good experience, and in some organizations the control laboratory is actually used as a training ground for newly employed college graduates. In such organizations the analytical-methods books

are virtually preliminary textbooks of the company's processes, so that from them an excellent general picture can be obtained of what goes on in the factory. In addition to this, such a training course gives an intimate knowledge of the raw materials and their properties, what characteristics make them acceptable and what ones make them impossible. An opportunity is afforded for becoming familiar with the intermediate products at every important step, and a knowledge will be gained as to when they are right and when they are wrong. Similarly a thorough understanding of the finished products will be acquired. Knowledge thus gained, by working with samples day after day—hundreds of them—will be ground in and fixed in a manner that cannot be matched by simply hearing about them or observing them. If a company proposing to hire a young chemist is going to put him into the control laboratory for training purposes for a limited period of time, he may regard it as that much more schooling, with pay. But if the company is going to put him there for keeps, he had better be magnanimous and let someone else have the job.

We cannot leave the subject of control analysis without mentioning one very important post in industry—that of head of the control laboratory. We say "post" because that is a word frequently used in connection with the word "diplomatic," and, if the field of chemistry holds any diplomatic posts whatever, the job of head of a control laboratory is at least two or three of them.

Consider the irate foreman who has just drummed off 200 drums of some product that turns out to be a shade under specification. He will have to rework it all, thereby running his costs up and his standing with the management down, unless the laboratory passes it. Are you sure, Mr. Laboratory Head, that your analyst did the work right? Don't you think the stuff will get by with the customer, and can't you pass it?

Think of the superintendent who is going to have to report a big loss of material if the results of your analyses of his inventory samples are what they seem. Are you certain your workers shook the bottles before taking their samples out?

Regard the sorrow of one of the plant chemists who sat up half the night taking hourly samples,

which he left where you would find them in the morning and on which he would like two days' work done by three o'clock this afternoon. Are you sure you can't let something else go and rush these through? This is mighty important, you know! And if you do rush them through and they don't turn out as they were supposed to, are you sure the results are accurate?

Give thought to these and dozens of similar situations. Remember how many places there are where an analysis may go wrong. Keep in mind that your "analysts" are not chemically trained, that they are just boys who have been taught to carry out certain manipulations. You will appreciate the difficulties met by the head of a control laboratory. If ever a man needed patience, tact, and intestinal fortitude here is the place. In case you are looking for a character-building job, this one unquestionably is a "wow," but unless you have a fund of patience greater than has been given to most of us, don't take it on for your life's work if you can help it.

What a confusion of ideas we have set forth about analytical chemistry. First we say it's im-

portant; then we say it offers no future. Next we say it is good training, and finally we close on a note of pity for the man responsible for control work. How about it all?

Well, what we have tried to say may be summed up in something like this: Analytical chemistry is tremendously important. It should be thoroughly understood and its possibilities and limitations appreciated by anyone essaying chemical work, but it must be regarded primarily as a tool to aid in other lines. As a field with a future for the chemically trained, it is usually not a promising job.

In discussing analytical chemistry so fully we have got considerably off the track, so let us return to our standards and mention again what was implied a while ago, that teaching analysts how to make tests calls for another set of instruction books as complete and detailed as those previously mentioned as being necessary for the guidance of plant operators.

When we consider how important it is that all these books, both those for the analysts and those for the plant operators, be not only accurate, but easily understood, we realize that one of the most

important attributes of a standards department man is the ability to organize his information logically and to write it clearly. And lest someone get the idea that it is necessary to write these books only once, let us hasten to point out that in modern industry, with changes taking place as rapidly as they do, such books are in a constant state of revision. Clear writing not only is necessary when the books are first prepared; it is needed daily.

Finally, another phase of the work of a chemist in standards has to do with his relationships with other people. So much of his time is spent in bringing instructions to the attention of factory operators and so much in checking up on the actual work of these operators that, unless he is able to gain their confidence and win their cooperation, they are apt to think of him as an enemy spy rather than a fellow member of their organization. Consequently the standards man must have not only a chemical training, the ability to write, an aptitude for teaching, and a sense for finding where conditions are not just as they should be, but also the knack of making himself welcome among the factory men with whom he has to work.

Chapter III

RESEARCH AND PLANT DEVELOPMENT

There are some who do research* work; into the deep,
deep stuff they grope.
Learned chemists.
Bum! Bum!
High-brow chemists.
And others may nurse a process which some day will work,
they hope.
Earnest chemists.
Bum! Bum!
Patient chemists.
Some work with hydrogenation machines, learning all
their wondrous ways,
And soon they'll give us castor oil we'll think is mayon-
naise,
Then we won't be quite ourselves again for days 'n'
days 'n' days.
That's not just chemis-
try! Bum!
That's also physics!

The word "research" is one of those choice ones that the nontechnical person recognizes as one he

* You will not get the beautiful musical flow of the words in this passage if you mispronounce "research." The accent should be on the second syllable, thus, "There are some who do re*search* work."

has seen in some impressive connection, but the exact meaning and implications of which may be somewhat vague, hazy, and indefinable. It is one of those powerful words which, like radium, vitamin, electron, ultraviolet, and so forth, our brothers in the advertising fraternity use on us to stun, but not kill. But what does it mean? Such different things to different people!

In chemistry there are some who act as if they felt that nothing less than a study of the ultimate composition of matter were deserving of the term "research." Those are the chaps who read somewhere that "the permissible orbits" of something or other "are regulated by the quantification of the angular momentum or rate of sweeping areas." Then they run their fingers through their hair, if any, and continue reading, "So far as any are circles, their radii still proceed" from somewhere to somewhere "as the squares of the natural numbers." Well, that's that.

The members of another group, while not insisting that the word be reserved for any particular field, nevertheless hold a conviction that research must not be tainted with commercialism in any

way. It must be "pure" research and, by inference, the purer the better.

In contrast to the foregoing there is that "practical" group which craves greater yields from some perfectly respectable reaction that is already making a living for several thousand people. More completeness to that reaction means more dividends, and, while these "bigger yield" researchers are regarding the high-brow electron chasers and the other pure researchers with some awe and with perhaps just a tinge of pity, they will feel that research has nobly met an urgent need if it can help them to greater production.

The dictionary, however, tersely informs us that research is "studious inquiry" and if we accept such a definition, even qualifying it as "chemical research," the word becomes so all-embracing that it covers too big a field.

Probably no two large industrial organizations include in their chemical research departments exactly the same types of work, and, since industry itself is not consistent in what the field embraces, it is not to be wondered that the matter is hazy to those outside of industry.

We can, however, get our bearings somewhat by arbitrarily defining research as that phase of "studious inquiry" into the chemical problems of industry which deals with more or less fundamental problems and which is carried out, for the most part, on a laboratory scale. Frequently its objective is the acquiring of basic scientific information, the solution of problems that have no immediate practical importance. Anyone can, without a great deal of difficulty, pick plenty of flaws in this definition. For instance, all research departments spend an appreciable amount of time on problems that seem piddlin' and certainly are far from fundamental. Again, all of them frequently have occasion to work on other than a laboratory scale. But as a means of giving a fairly accurate rough idea the definition still stands. We shall have more to say about research in a moment, but before we do we should say a word about another type of investigational work, namely, plant development.

Plant development is a coined expression used to designate a particular kind of technical work in industry. It is, in general, applied to investiga-

tional work that deals with problems of more or less immediate practical value and it undertakes the study of these problems, for the most part, in equipment of larger than ordinary laboratory scale. It may be thought of as research in tubs and tanks rather than in beakers and flasks. As with our definition of research, plenty of objections can be raised against this definition. Frequently plant development work deals with fundamental problems of no immediate practical value and often it involves a great deal of laboratory work. In spite of the inadequacy of the definition, however, it will serve to outline the general field that we consider as belonging to plant development.

One can readily see that there will be a good deal of overlapping between the fields that we have just defined. Because of this we are going to discuss the two together and we are not going to try to draw a distinction between that which we consider as belonging to one and that belonging to the other. In industry the actual division between the two is dependent on many local factors that need not be considered in the general survey we are about to undertake.

Research and plant development concern themselves, of course, with the three major divisions that we have been using throughout our discussion, namely, raw materials, processes, and finished products. To the layman it may appear strange that in a well-established business there should be much occasion for investigational work in these fields, for it would seem that a concern that had been operating a hundred years, or fifty, or even five, would have things pretty well worked out. The trouble with that thought, however, is that it presupposes a fixedness about production that does not actually exist. As a matter of fact, practically nothing in industry remains the same. Changes in markets, in styles, in living habits, in a thousand and one things, necessitate corresponding modifications in manufacture, and as a result the successful industry must keep alive to the possibilities of things being different and must be prepared to meet altered conditions.

Consider the rubber tire for instance. It used to be guaranteed for 3,000 miles and it was so hard that every jolt that the road gave it was promptly passed on to the motorist. Now we have tires (or

at least we did till the Japs got active) which are easily good for 20,000 miles and which are so cushionlike that, instead of passing road shocks on, they absorb a great proportion of them. What is the difference? Recent tires still had a foundation of cotton covered over with rubber that had been compounded with certain additional things. As the study of tires progressed, there were new "additional things" which the old-time tires did not contain and which made the advantages of the newer ones possible. And the hunt for "additional things" goes constantly on! What effect has this ingredient? What that? Why does the product fail, and how can we overcome that failure? As a result of that constant study we find today's latest "rubber" tires made on a foundation of rayon instead of cotton and without rubber at all!

Again, consider the trusty bar of soap. For years it helped the washboard keep us spick-and-span, but then came the washing machine. The bar had to be whittled up so it would dissolve faster. Enter the soap chip. But why stop there? If a chip will dissolve more quickly than a bar why not something even more rapid? The answer was the

granule, which is a soap bubble, literally, in the wall of which the soap is so concentrated that the bubble hardens and retains its form. But in this field, too, the study has gone on until the most recent granulated "soap" products are made without the chemical compound soap at all.

Even without these constant changes there is room for a great deal of study in practically every industry, for in very few, if any, is everything being done so well that improvements cannot be introduced, and further study in almost any line of endeavor will bring beneficial results.

To start a consideration of specific problems let us assume we have chosen some industry to study and let us consider the raw materials that are being used. We can even start our study before the actual processing of the materials begins. Suppose we pick out one item and give some attention to some of the questions we can ask ourselves concerning it.

What are the effects of various storage conditions on this material we are considering? If the effects are adverse, what can be done about it? Does the material deteriorate with age? It may be

something that oxidizes, dries out, decomposes, ferments, or in some other way loses value upon keeping. If so, can some special condition be devised to protect it?

Again, we may ask whether temperature of storage is a factor. If so, is a cooler place (or a warmer one) available? Does humidity affect it? If so, how can we keep it dry (or moist) either through choosing some different place of storage or through installing suitable humidity-control equipment? What action, if any, does light have on it?

If there are difficulties encountered in storage, can they be overcome by conditioning the raw material before storage? For example, cottonseed, brought in wet condition to a mill, deteriorates markedly because the oil held in the seed develops an "off" flavor when moisture is present. Consequently drying the seed before storing is an aid in preserving the quality of the oil held within the seed.

Still another way of conditioning raw materials before storage is to process them partially so as to get them past the stage where deterioration will take place.

Turning now from the storage of raw materials, we may ask how variations in the quality of each raw material affect the yield or quality of the finished product? What happens if the material is not up to its proper strength? Obviously if we accept something that is below strength, diluted, or adulterated, we are paying for something we do not get, but are there serious consequences in addition to that?

What about the effect of impurities? These may reduce the activity of the raw material chemically. For example, nickel catalyst becomes relatively ineffective if it contains any of the well-known catalyst poisons. Impurities may injure the quality of the finished product through some physical effect, as would be the case if a dark rosin were used in place of a lighter one in ester-gum manufacture. Obviously such a substitution would result in a darker colored ester gum.

How about the intentional addition of some substance to our raw material? For example, chlorophyll, a coloring matter sometimes used to make soaps green, has a much higher tinctorial power if a little copper salt is added to it. From

the standpoint of the supplier of chlorophyll, therefore, it would seem like a smart thing to add copper, thereby giving his product a higher tinting power or enabling him to add some inert diluent so he could offer chlorophyll of a definite tinting power at a lower price. But how would this be from the standpoint of the soapmaker? It just happens that certain metallic salts, and those of copper in particular, promote the rancidifying of soaps materially. Obviously, then, the introduction into soap of a copper-containing chlorophyll is actually a very undesirable thing.

We may next turn to a study of whether we can improve the quality of our raw materials by treating them in our plant before use. If impurities are harmful we can investigate whether purification is feasible, and, if it proves to be, we may want to add that as a normal step in our process.

Again, some form of activation of our raw material may prove helpful. This sometimes may be a chemical activation, such as the treatment of a bleaching earth with acid to make the earth absorb colors more readily, or it may be a physical

activation, such as the finer grinding of some pulverized material that is to enter into the reaction.

Turning from the raw material itself now, what about the containers our raw material comes in? Would the substance be kept in best condition if it came in bags, barrels, boxcars, or what? Or would it come in just as good condition, but at a lower price, if we bought it in some other form of container?

Still another point to consider about raw materials is whether we can do more than we are now doing in the matter of recovering and re-using the materials. Of course, most raw materials are used up in the process, but frequently there are some that are not. For example, a decolorizing carbon, after being used, still offers some possibilities, for it may be washed and subsequently treated to reactivate it, thus becoming available for reuse. But does such reactivated material give as good results as does the new, and can it be reconditioned more cheaply than the new can be bought? There is no use bothering to recover it unless some advantage is to be gained therefrom.

So much for existing raw materials. What about substitute raw materials? The immediate reaction to that question probably is that, if the present materials are proving satisfactory, why bother with casting about for substitutes. To that point the answer is simple. There are three reasons for looking for alternate raw materials. One is to enable us to make a better product. The second is to enable us to make the same quality of product at a lower cost or by means of more advantageous processing. The third, and in wartime perhaps the most important of all, is to permit us to continue making a product when the customary raw materials have become unobtainable.

Considering the matter of cost for a moment, we can readily see that it will be to our advantage to have raw materials that are interchangeable so that we can take advantage of fluctuating market conditions. If we have a choice of two or more materials for a single use we can buy the one that is currently the best value. Incidentally, it is a pleasant situation if we can let the man who sells us our raw material know that it is possible for

us to get something elsewhere that will serve our purposes. It keeps him so much more reasonable and attentive.

Right here, incidentally, seems to be an excellent place to make a very important point in connection with our raw materials. When we are buying raw materials we are buying, not goods, but rather what the chemist calls "properties." In other words, we are buying characteristics or attributes. What does that mean? Just this. We are concerned, not with what the materials are, but with what they will do. For example, suppose our factory is a paint factory and that we are buying white lead to make paint. In the last analysis, when we buy white lead the thing we are really after is not white lead at all, but rather that property or attribute which is described as "covering power." What we want is something we can put in our paint which will cause the paint, when spread on a surface, to cover that surface and make it look white. Of course, there are incidental factors such as the effect on the oil in the paint, the effect on the life of the paint film, and so on—but the primary thing we are buying

is white covering power. If we can get the same effect from some zinc compound or some titanium compound or any other kind of a compound, we are interested in it, assuming that its effect on other factors, such as durability of the paint film, and so on, is not objectionable in some way.

If there are two or more raw materials that have the properties needed for a given manufacturing process the next problem becomes one of evaluating them. One may cost twice as much per pound as another, but if its effect is twice as great it may well be worth the difference. In fact, it may permit some operating short cut or convenience which makes it more desirable even though its actual effect is not twice as great. With the foregoing in mind, then, we can see that our study of substitute raw materials may follow along several lines.

Among other things we shall make a comparison of kindred raw materials. If our process, for example, is a textile process in which palm-oil soap is used, how about using tallow soap or olive-oil soap or oleic-acid soap in its stead?

Again, we shall study the effect of blending raw materials or the intentional addition of foreign substances. Perhaps a catalyst that we are using can be made more active by adding to it a small percentage of some other material that by itself is no catalyst at all.

We shall study materials with similar properties. If our problem is one of heating a still, for example, shall our source of heat be a solid—coal or coke—or shall it be liquid—fuel oil—or shall it even be gaseous—natural or artificial gas? Economy may suggest one; simplicity of operation may demand another. We must consider the merits and shortcomings of each for the particular problem at hand.

Perhaps we can improve the quality of our raw material, or get the same quality at a lower price, by choosing a material made by a process other than the one ordinarily used. For example, if we are using aniline in our process, we have a choice between that synthesized from nitrobenzol on the one hand or from chlorobenzol on the other. Is there any preference, under our particular conditions, for one over the other?

Again, if our raw material is a natural one, differences in treatment of it may mean differences to us. Copra (coconut meats), which is used to make coconut oil, is frequently dried where it is grown and shipped to some other point to have the oil pressed out of it. The drying may be sun drying or it may be kiln drying. Does it make any difference in the mill when the oil is pressed out which method of drying has been used?

Or we may choose a synthetic raw material in place of a natural one. If the price of a natural product gets too high, or if its source is no longer available to us for some reason, a material of synthetic origin is frequently substituted for it. The war has brought many instances of this sort of substitution, for example, synthetic rubber. Sometimes we choose a natural product from one geographical location in preference to that from another if quality or cost factors make this desirable.

Still another possibility to be considered in connection with raw materials is making these ourselves instead of buying them. The determining

factor in deciding whether this is wise or not is usually one of cost.

What about the physical form of the materials? This has to be considered not only from the standpoint of cost, but also from that of convenience of handling. Is it to our advantage to receive it as a solid or as a solution? For example, calcium chloride is available in solid form in metal drums, but it is often used as a solution. Hence, to use it from the drums involves splitting open the container, breaking out the chunks of material, dumping them into water, and dissolving, all of which costs money. On the other hand, the material can be bought in solution in tank cars. To use it when purchased in such form involves simply pumping it, or even just allowing it to flow, out of the tank. But when it is bought in solution there is the matter of paying freight on water. Under the conditions of our particular plant, which is the cheaper?

In the case of some solid materials there is a choice between flakes, with their relatively great surface exposure, and cakes, which are compact and hence easily handled. Stearic acid, for ex-

ample, can be had in either form. Is it more advantageous to us to have the one or the other? Price and convenience again have to be considered.

Turning now from raw materials, we take up the work of the technical investigator in connection with processes and equipment. The first thing we shall want to do is to acquire a thorough understanding of each step in the process as it is being carried out and of each piece of equipment that is being used. What are the chemical reactions involved? What physical changes are brought about? Why is the temperature of the reaction what it is? If a vacuum is maintained, how much and why, and what would happen if it were more, or less? As to the equipment, we must know not only just what chemical and physical changes are going on in each unit and why those changes are desirable, but also what conditions of the equipment are favorable to the beneficial changes and what ones promote detrimental changes. To learn the latter we shall have to study systematically such factors as time, temperature, load, and so forth. For example, if the piece of equipment we are studying is a still,

what is the most desirable-sized charge to feed to it at the start of the operation? How rapidly should distillation be carried out? If the still is operated under a vacuum, how much of a vacuum should be carried? Questions supplementary to the foregoing are: What will happen if a larger charge is fed? A smaller one? What if the distillation is carried on more rapidly? More slowly? What is the effect if a higher vacuum is employed? A lower one? If some desirable end cannot be attained without, at the same time, some undesirable condition entering in, then what can be done to obtain the beneficial effects without the detrimental ones?

To help in gaining an understanding of the whys of both the process and the equipment, one of the first and most important tasks which the investigator can set for himself is to make a set of "toy" equipment. On the face of it that may sound a little silly, but one of the fundamental jobs in connection with the studying of a process is to be able to carry it out on a laboratory scale with such exactness that the results obtained in the laboratory can be reproduced in the plant. It is to enable

the investigator to do this that the small-scale equipment is necessary.

To the man who has not tried to duplicate plant performance on a small scale the difficulty of such an undertaking may not be apparent. But when we consider, for example, the difference in the time it takes to cool a beaker of liquid from, say 100°C. to 25°, just by letting it stand at ordinary temperatures, as compared with the time required to cool, say, 5,000 gal. of the same material stored in a tank, over the same range of temperature, we begin to get an insight into some of the difficulties involved. Let us suppose crystals are separating from this solution. Those depositing from the relatively quickly cooling beaker will certainly be far different from those separating from the slowly cooling large mass. Or again, let us suppose the material is liquid at 100°C. but solid at 25°, and let us assume that our problem is one of settling out certain constituents from the liquid. Obviously the slowly cooling large mass will have a much greater opportunity to settle before it solidifies than will the quickly cooling beakerful. We therefore have to devise a

means of cooling the small mass at the same rate as the large. It may be that ordinary laboratory equipment can be used to duplicate the plant conditions we are studying, but the chances are that it cannot. The resourceful investigator not only makes use of the standard equipment available, but also calls on the glass blower, the machine shop, and the carpenter shop to devise small-scale units for reproducing the conditions existing in a factory process.

It hardly seems necessary to discuss it, but someone may raise the point as to why we want to experiment on a small scale. Why not do our experimenting on the regular production units?

Sometimes the large units can be used to excellent advantage and when they can it certainly is preferable to use them. However, there are two very good reasons why that usually is not a feasible plan. In the first place, production units are ordinarily being used by production men to produce, and the experimenter is an intruder, a "clutterer-upper" of normal free-flowing activity who is not going to be warmly welcomed. He cannot carry on his work without being in the

way and consequently he is usually kept out. In the second place, when one is experimenting he is gambling on the outcome. True, he probably plans his experiment to give a favorable result, but things may not happen as he expects, in which case it is ever so much more comfortable to ruin a few hundred grams of material than a few thousand pounds.

If it remains necessary to carry on experimentation on a production scale the two factors we have just mentioned will prevent a lot of experiments ever being tried at all. Every investigator sooner or later gets ideas so crazy he would not feel like risking their trial on a big scale, but in a small unit he is willing to take a chance. And sometimes such crazy ideas work.

The small-scale equipment frequently can do things which large-scale cannot. For example, it is frequently easier to get a high vacuum on a small scale still than on one of a full plant size. Consequently with our small-scale equipment we may be able to go even further than before in a systematic study of the results obtainable by varying the conditions of the process. The factors

of temperature, pressure, time, and so forth, to which we gave attention on our plant-size equipment, can receive a more complete and detailed study when our small-scale equipment is available.

The nature of the process we are studying will, of course, suggest what variables are worth looking into. It is not practicable to try to set down all the types of things that are worth studying. But an active imagination turned loose on any process will think of many things that will bear studious inquiry.

Such a survey of the effects of varying a process as we have just discussed will, in all probability, result in the finding of ways of simplifying the process or of altering it in some beneficial manner.

Again, small-scale equipment and a thorough understanding of the process can sometimes be turned to advantage in locating trouble in large-scale production. True, after we have gained a thorough understanding of the process through our study we shall have less difficulty in our big-scale operation. But let us assume that in a process consisting of several steps some trouble has arisen in

the large-scale operation which we cannot correct. Our miniature equipment proves a valuable tool in determining the source of the difficulty. We take a sample of the product after the first step of the process and finish it in our small-scale setup, where we can control conditions very carefully. The finished product from the sample turns out to be standard. That gives big-scale operation No. 1 a clean bill of health, for if the sample had been off, the damage would have been done to the product that was finished up in the small-scale unit.

Next we take a sample from big-scale operation No. 2 and finish that up on our small equipment. This time perhaps the finished product comes out subnormal; we have therefore convicted operation No. 2 of being at least partially responsible. Similarly we check the other operations in turn and then, having found which one, or ones, are giving the trouble, we concentrate our investigation in the plant on those points which have been shown to be wrong.

Another use made of the small equipment is in the application of a process to other materials.

Suppose we have developed a machine for puffing wheat to make breakfast food. What will we get if we puff other materials with it? For example, can we take some organic waste product and, by puffing it, develop a porous product that is suitable for insulating purposes?

Still another use of the small-scale units is in the production of small batches of either regular or special materials for submitting to prospective customers. Suppose our plant units cannot operate on a quantity less than 30,000 lb. and that one of our most important customers has asked for a 10-lb. sample of a particular product which we haven't in stock. It is a real help to have a small-scale unit, which will enable us to make the proper-sized batch and at the same time to duplicate plant production.

So far we have kept our investigator on existing processes and equipment. What about new procedures and new machines for making the same products?

There are two reasons for considering a change —to produce a better product and to produce a product of the same quality at a better price. But

with these two objectives before him every alert manufacturer is constantly on the lookout for a better way of doing what he is doing or for better tools with which to do it; and his research and plant development men are looking for new processes and new equipment to replace or alternate with existing ones.

There are three distinct sources of ideas for new processes and equipment.

1. There are, of course, ideas that originate within the company. Men who are constantly working on any product or line of products will naturally get new ideas for producing their products.

2. The technical literature, particularly current periodicals, will often suggest processes or new reactions to be tried out or equipment modifications to be considered.

3. Outside interests, either other technical organizations or, sometimes, an independent inventor, will suggest something new for consideration. From whatever source the new idea may come it must be carefully analyzed, its advantages and disadvantages weighed, and a decision

reached as to its value in comparison with that which is already in use.

We turn now to the investigations of the research and plant development departments on the finished products. In the first chapter we indicated that much of the work on these would be done by a separate unit, the products service department. However, there is also a large field of study on products that belongs to the research and plant development departments. In fact, all the work that these departments do on raw materials, processes, and equipment is, in the final analysis, for the purpose of improving the product, making it last longer, making it cheaper, or obtaining some other beneficial result. So in a sense everything we have said in this chapter has had a bearing on products. Furthermore, in order to be able to direct their efforts toward a uniform or an improved product, these departments must have before them a rather accurate picture of what the desirable qualities of the product are. They must learn not only what the physical and chemical characteristics are that make for a good product, but also the effect of variations in these

characteristics on the value of the finished product in use.

In all their studies of raw materials, processes, and equipment, the research and the plant development departments will direct their attention toward learning how they can maintain the desirable characteristics of the products involved, or even improve them. They will seek to give the product a better appearance, color, odor, feel, and so forth, and they will try to improve its performance through making it work faster or more thoroughly. If the product happens to be one that deteriorates with age, they will try to make it keep longer. They will work out proper storage and warehousing conditions, taking into account time, temperature, humidity, and other factors, just as they have to consider these in connection with raw materials.

They will work out proper containers, packages, and wrappers. This will involve studies of materials such as paper, cardboard, inks, adhesives, cans, bottles, and so on, and it will call for tests such as warehouse tests and trucking, shipping, and storage trials, together with in-

vestigations of the feasibility of shipping in bulk in tank cars or boxcars rather than in smaller containers.

The studies of the research and plant development departments will not be confined to the existing products. The workers in these groups will constantly be on the lookout for new products as well. Such new products may develop from various sources. For example, an existing product may be so modified that it is put on the market as a new brand. Such was the case when ordinary gasoline was transformed, by the addition of tetraethyl lead, into an antiknock gas. Again, a new product may be developed which will supplement an existing product. Such a case was the making of an automobile polish to be sold as an adjunct to the normal gas and oil business of a filling station. As another possibility, a new product may develop from the application in an entirely different field of some material which is currently being processed. For example, the petroleum industry introduced a brand-new line and entered a new merchandising field when it added to one of its distillates, which is a close

relative of gasoline and kerosene, an appropriate amount of pyrethrum extract, thereby producing a very effective fly spray.

Another source of ideas for new products comes through the working up of by-products. For example, the problem of still residues in the coal-tar industry led to the development both of a very satisfactory road material and of a good roofing.

Another phase of the work of the research and plant development departments on products has to do with their duplication of competitive products or the development of new products to compete with the competitive ones.

Having carried our investigational work from raw materials to finished products, we can now consider a few additional fields of work that are carried on in conjunction with those which we have already discussed.

The first of these is library work. It is fairly well known that the logical beginning of any study is to find out what, if anything, is already known on the subject, and the normal place to turn to find that out is to books. In a small company

every investigator will, of course, have to do his own library work and perhaps even supply his own library. In larger organizations, however, a library is usually maintained which contains books and periodicals pertinent to the industry. When such a library is provided it is often presided over by a technically trained librarian whose duties include the following:

1. To see that the library does contain the literature that is of value to the organization.

2. To read the literature dealing with the industry concerned and to be sure that the various members of the chemical staff see such books or articles as would be of help to them in their particular line of work.

3. To look up specific facts or lines of information for chemical division staff members. While it is, of course, obvious that any investigator will, himself, want to keep well abreast of the knowledge in his field, nevertheless there are frequently times when particular facts or lines of study need to be run down and it is often in the interest of efficiency to have one person who can do that sort of thing for the organization.

4. To save some of the wear and tear on the somewhat rusty French and German of staff members by doing a certain amount of translating for those who need that kind of help.

The second additional field we want to discuss is patent work. Naturally systematic investigation leads to patentable ideas, and it is important that these be properly taken care of. Hence in large organizations a patent department is maintained for that purpose. Its duties are:

1. To keep informed on patents, both foreign and domestic, that deal with matters of interest to the organization.

2. To call to the attention of the members of the chemical staff such patents as may be of interest to them.

3. To prepare and file applications for patents on ideas developed within the company.

4. To follow up these applications with the Patent Office, studying the office actions that are taken on the various applications, preparing and filing proofs of invention, and preparing suitable amendments in line with the Patent Office requirements.

5. To supply the technical aid necessary in patent suits.

One may wonder from the foregoing whether this job is one for a chemist or a lawyer, and the answer, of course, is that the man who handles the job successfully must be something of both.

The third additional field of work spreads itself over many other fields. It is the selection or development of proper analytical methods. We have already had quite a lot to say about analytical chemistry, much of it very discouraging, but the subject we are about to take up here is vitally important to successful manufacture. While the control laboratories and the standards department are responsible for actually doing the analytical work, the research department is the one primarily responsible for developing the proper analytical methods.

Suitable analytical methods must be chosen to evaluate raw materials, control the processes, and assure the quality of the products, but because such analytical work is a direct charge on manufacture it must not be allowed to cost any more money than is necessary. Consequently short cuts

must be developed where possible. Analyses must be put on a production basis. When feasible, advantage must be taken of such rapid measuring instruments as the microscope, the refractometer, or the spectroscope. Often special machines can be developed to promote speed and economy.

In addition to the control analyses, most large manufacturers run "accounting analyses." As suggested by their name, these are for the purpose of keeping proper accounts of materials. In other words, they help the cost department to maintain a "material balance," just as you or I keep a bank balance, or try to at least.

Still other analytical work often is necessary in following current research or plant development problems. Sometimes known methods can be adapted to this, but often entirely new ones have to be worked out. Inasmuch as the research in question is to be interpreted or evaluated in terms of the analyses made, it is, of course, essential that the analytical work be properly done. Because the analyses on investigational work often are not of a kind that can advantageously be done by the "lab boys" who do routine work,

they are carried out to best advantage by analysts of a higher degree of skill, working directly in the research department.

There is always a certain amount of work to be done in standardizing the analytical methods in use in one's own plant with those of outside agencies, such as the government laboratories, technical societies, suppliers of raw materials, customers, and others. Purchases or sales may be involved, or it may be merely some cooperative work for the sake of a better understanding in some industry, but, whatever it is, it calls for painstaking technique. Here again an analyst with really good chemical training is essential.

Another analytical problem which frequently comes to the fore is that of developing a means of expressing intangibles, such as color, odor, consistency, and so on, in numerical terms. We can argue interminably about some of these things because they are matters of personal opinion or do not lend themselves to being accurately described. You and I can agree today, perhaps, as to which of two objects is the whiter, but how shall we record our findings so someone else may

know a year from now how white was the white we saw? When we can learn enough about some of these factors to be able to report them in measurable units we add another valuable tool to successful manufacture.

A final field of the research worker is a sort of catch-as-catch-can one. You may be surprised to find it included as part of the job, yet sooner or later it bobs up in practically every company. It involves doing all sorts of odd chores for individuals within the organization, and it may range all the way from learning something of the mineral content of the unparalleled water that flows from a hidden spring at the vice-president's summer home to prescribing a treatment to rid the sales manager's swimming pool of objectionable algae. Or some member of the organization may be elected to his village water board, and you may have to help him work out a suitable water-softening plant for his community. It is clear, of course, that work of this sort doesn't make much money for the company, but it is a type of service that it is sometimes better to render than refuse.

The ultimate in this sort of work that ever came to the writer's attention was a request from a purchasing agent who had remained a bachelor for many, many crusty years and then finally took unto himself a wife. The pent-up romance of all his solitary life burst forth in the sentimental request that the laboratory take the orchids that his bride had worn and preserve them in some effective manner so that they could be handed on to posterity, if any. And that from a purchasing agent!

We are reaching the close of our chapter on research and plant development. Logically, we should sum up what we have had to say in a few concise sentences. But when we try to do that we find ourselves balked by the fact that the territory covered has been so broad it doesn't want to condense. Let us not try it. Let us leave the subject with the observation that the "studious inquiry" with which the research and plant development departments concern themselves leads into every crevice and cranny of the manufacturing picture.

Chapter IV

PRODUCTS SERVICE

Now some of us call on the customer to find out what he wants.

Traveling chemists.
Bum! Bum!
Inquiring chemists.

And some ot us run complaints down, bearding kickers in their haunts.

Unraveling chemists.
Bum! Bum!
Perspiring chemists.

Some explain our wares in our salesmen's schools so those boys will be wise,
And some of us try to work out new ideas to advertise
So folks will buy from us instead of from the other guys.

But we're chemists.
Bum! Bum!
We're the chemists.

After all is said and done, a business thrives and grows, if it does, because of one class of people—its customers. To be sure, good equipment, efficient manufacturing technique, and skilled personnel contribute to the production of goods that attract buyers, but it is the buyers

themselves who supply the money to improve factories, to buy better equipment, to pay wages, and to disburse dividends. With the realization of the importance of the customer it becomes clear that a fairly careful study of his likes and dislikes is in order. To gather information concerning this all-important person and to help devise means to serve him better is the function of the products service department.

Obviously if we are to learn anything about a customer's reaction toward our products we have to develop his point of view and appreciate his problems. The surest way to do this is to use our products in the same way and for the same purposes as he uses them. Thus, if we are selling the laundry trade, for example, we shall do well to study the laundering processes, to learn the principles involved in successful laundering, to learn the effect of various cleansing materials, to develop the very best practices for meeting certain specific conditions. In fact, we shall apply to the laundry the very same principles which we discussed in Chaps. II and III as applying to our own business. This means we shall make laboratory,

semiplant-scale, and full-plant-scale studies of the laundering process. In other words we shall go into the problems of our customers so thoroughly that we shall be qualified to serve as a consulting laboratory to those industries that use our products.

If an organization is to be prepared to serve in the capacity indicated above two things are necessary. In the first place, technical men have to be put in a position to meet the customers. They have to "come out of the kitchen," put on their Sunday suits, and circulate in the trade more or less as if they were bona fide, garden-variety traveling men. In the second place, these men must have a sufficiently good technical background to be able to do for the industries they visit substantially the same sort of work that our research and plant development men do for our own industry. Of course their major attention is devoted to that portion of the industry to which they are selling which concerns itself with our products, but they cannot stop there. They must be ready, if necessary, to undertake work on other raw materials used by the industry, on

equipment, processes, packaging material, in fact anything that may come up. There are, of course, practical limits to how far they are justified in working on problems not immediately connected with their own products, and someone may well ask why they should spend any time at all on problems other than those dealing with the use of their own commodities. To that question there are several answers.

In the first place, there cannot be a proper understanding of the requirements of our product unless there is some knowledge of the related problems.

In the second place, if a complaint on our product arises it is not enough to assure a customer that we have checked the quality of our material, that we have found it satisfactory, and that his difficulty therefore must lie elsewhere. We are in a much better position if, in addition to reassuring the customer about our product, we are able to help him locate the actual cause of his trouble.

In the third place, this more thorough knowledge of the customer's problems may lead to the discovery of new uses for our products, uses in

phases of the customer's work other than the ones in which he happens to be using our products at the moment. Or we may find a problem that can be solved by the development of a new product. An example that illustrates this last point is the introduction a few years ago of a new shortening to the baking industry. For a long time practically everyone had recognized that bakers' cakes did not taste so good as housewives' cakes, but no one ever did much about it except to urge the baker to make better ones. Comprehensive instructions, or even pertinent suggestions, on how he was to do it were lacking. In fact, no one knew exactly why bakers' cakes were different. Then a real study of the matter was undertaken by a group of chemically trained men. The first thing they did was to take an almost endless number of household cake recipes, to classify them, and then, so they could be compared with bakers' formulas, to convert them from cupfuls, teaspoonfuls, pinches, and so forth, to pounds and ounces. The result was a revelation. No wonder the bakers' cakes and those of the housewife did not taste alike. Below is a typical com-

parison of homemade cake and old-style baker's cake, both calculated on the basis of 100 lb. of flour. It will be noticed that, where the housewife uses sugar in the ratio of 118 to 100 lb. of flour, the baker used only 90. Similarly, where the housewife used 55 eggs the baker used only 42. Corresponding differences may be noticed in the other materials. You would not expect cakes made from such different proportions of ingredients to be very much alike, would you?

Ingredients	Old-fashioned baker's cake, pounds	Homemade cake, pounds
Flour	100	100
Sugar	90	118
Eggs	42	55
Milk	58	66
Shortening	35	48
Salt	2½	2½
Baking powder	3	4

The next logical step was to make up a baker's formula patterned after that of the housewife. When this was done, however, the result was a sad one. The cake mixed on the machinery that the baker used "fell" and was wholly inedible.

Yet to maintain production he had to work on a large scale, and it was his machinery which enabled him to do so. To make a long story short, a shortening was developed that enabled the baker to use proportions of ingredients comparable to those in the housewife's own recipes and yet to employ his machinery to produce cakes in quantity. Thus a new product, developed as a result of chemists' studies of customers' needs, has revolutionized the established practices of an entire industry.

Next we turn to a phase of the products service department's activity quite different from the foregoing. The familiarity with the customers' requirements previously discussed furnishes the background for a testing unit that may be designated as a "quality-control unit." We learned in our chapter on "Standards" of the careful analytical control exercised in a modern factory to maintain a uniformly high quality. But that control is based on certain analytical measurements. As a check on that, the quality control unit of the products service department inspects and uses samples of the various products

in the same way the ultimate consumer will use them. For example, if it is a shortening that is being manufactured, actual baking tests will be run with a sample of every batch made, just to be sure that in the hands of a baker the shortening will behave as he will expect it to.

Again, an alert manufacturer is interested not only in his own products, but in those of his competitor as well. For this reason he will have his quality-control unit follow systematically the products of his competitors. Such a study may serve two purposes. If the competitive product is better in some respect, the necessity for improving his own product in that direction becomes apparent. If the competitive product is poorer, a potential "talking point" has been uncovered for his sales department.

Complaints, improperly handled, almost invariably lose a customer. Properly dealt with they may not only hold him, but may even build substantial good will. As a result, one of the important problems of a products service department is the efficient handling of complaints. We have already touched on the fact that it is not enough

just to deny that our product was at fault; it is necessary, in addition, to locate the real cause and explain to the customer's satisfaction that the complaint against us was unjustified. Unfortunately, however, even in the best of manufacturing concerns, complaints may sometimes be justified and when they are it is up to the products service department to analyze their cause and to see to it that the unfavorable conditions that were responsible are corrected. A complaint is often a straw showing which way the wind is blowing, and every one is deserving of intelligent attention.

Because of the background that contact with the trade gives and the knowledge of performance that comes from constant usage study of products, several other opportunities for a products service department become apparent. We have already hinted at the fact that this work may be of direct help in sales and advertising. This is true because the products service department is in the position of knowing not only the customer's needs, but the capacity of our products and our competitors'

products to meet those needs. For this reason this department can develop sales and advertising points that might otherwise be missed. Of course, in this enlightened day and age, there are a good many sales and advertising points which, we are happy to say, the chemist had no hand in developing. Even in connection with these, however, he may be of some use, for if a competing company has made some outlandish claims for its product, our chemists, knowing what the product will really do, can sometimes develop effective refutation. Thus suitable information can be given to salesmen to aid them in helping their customers see the fallacies of the statements that competitors may be making.

Our own advertising copy can also be advantageously reviewed by the products service department for several reasons.

1. Technical inaccuracies may be caught and called to the attention of the advertising department so that they can keep their stories in line with the facts. Of course, as suggested before, there are some advertising departments that do

not appreciate help of this sort. Some of them seem to prefer to take the point of view that when the virtues extolled by the printed page far exceed the performance of the product in question, it is not the advertising that is at fault at all. They prefer to argue that the advertising is really splendid, that the merchandise is at fault because it will not do the things the advertising says it will. However, advertising departments these days are, for the most part, quite willing to enlist the chemist's aid in fact finding.

2. Statements which may be irritating to our customers may be avoided. For example, a company selling soaps to both housewives and laundries should not let its household advertising be of such a nature as to reflect on the quality of work done by the commercial laundry, for if it does that company's commercial-laundry customers will let themselves be heard from with vim, vigor, and diminution of orders. Of course, the sales and advertising people themselves are watching this point, but the familiarity the products service department gains with the customer's point of view often enables this

department to sense difficulties that others might overlook.

Our own and competitive advertising are not the only forms of printed material we must watch. Outside agencies occasionally make statements which have a bearing on our business and which need correcting if they are inaccurate.

There is the case of the learned (?) health authority (?!) who used the columns of a metropolitan daily paper to warn people that a plague of goiters was just around the corner. He based this alarming prophecy on the following line of reasoning: (1) Goiter is likely to result if the diet is deficient in iodine. (2) Hydrogenated shortenings, which are being consumed in large quantities, are made from oil, the hydrogenation of which has resulted in a lowering of the iodine value. (3) Certainly the wide use of an oil or fat that had had its iodine value reduced would bring on an increasing number of cases of goiter, if not a positive epidemic.

In case the foregoing should by any chance be read by anyone who is not somewhat conversant with chemistry, let us hasten to explain that the

iodine value of a fat has nothing to do with the amount of iodine it may or may not contain. As a matter of fact, fats or oils do not *contain* iodine. The iodine value is an analytical measure of certain characteristics of the oil, a fact which is familiar to thousands of students who have taken chemistry in college but about which the pseudo health expert had never heard.

An equally sensible theory concerning the digestibility of edible fats was once expounded in a book that had a wide sale. According to this book certain fats, when used for deep frying, become indigestible because portions of the fat boil off, leaving behind them other portions that have a boiling point too high to permit them to boil away. In the course of time so much of this high-boiling-point fat accumulates in this way that the frying fat becomes terribly indigestible. The chief trouble with this story is that it is untrue. As anyone knows who really knows anything at all about the fats used for deep frying, such fats do not boil at all; hence the idea that a portion of them boils away becomes recognizable as sheer nonsense.

Other forms of help that a products service department can give to the sales and advertising departments include:

1. Writing instructions for the use of products.

2. Conducting correspondence with customers, with allied trade groups, and with various technical groups along lines that help distribute general information about products.

3. Preparing convention displays of a more or less technical nature.

4. Giving talks before trade conventions and technical society meetings.

5. Preparing bulletins and booklets of a publicity or advertising nature. These may be highly technical, directed at scientifically minded readers, or they may be so written as to be informative to the layman.

6. Conducting schools for salesmen, to inform them about the desirable qualities of the products they sell and to give them information concerning the uses of the products.

Another use for a products service department arises when the research department develops an improvement in one of the company's products or

when some outside agency, either an inventive individual or an industrial concern, offers the company some new product to manufacture and sell. In such cases the products service department is in a good position to evaluate the improvement or the new product in terms of how it will appeal to customers and to help to decide whether to adopt it or reject it.

If you have begun to wonder at this point whether we are still talking about a chemist we might ask in reply, "Why not?" Is there any reason why these various jobs that deal with facts about things should not be handled by a man who has spent time training himself in learning to evaluate facts and in making a study of what these things really are, how they behave, and how they can be made to behave differently if necessary? Is there any reason why the chemist should pass his findings out through the laboratory door and let someone on the outside interpret them? Can he not go along with his facts and bring the benefit of his familiarity with them to their ultimate application?

Chemistry need not be a chain holding a man in a laboratory where he works out answers for Tom, Dick, and Harry on the outside to take and make use of. Chemistry should be a tool which a man uses as a supplement to other capabilities and which thus enables him to meet Tom, Dick, and Harry, in any corner of industry or commerce, and help all three of them to do a better job than they had been able to do before the tool of chemistry was brought to their attention.

Chapter V

THE KIND OF CHEMISTS INDUSTRY WANTS

We're a hopeful group of students setting out to find some jobs.
We want to be chemists.
Bum! Bum!
We want to be chemists
We would like to have our money come in gobs 'n' gobs 'n' gobs—
If that happens to chemists.
Bum! Bum!
If that happens to chemists.
There are some of us who made the highest grades in all the class,
And some of us were happy if we managed just to pass,
But bright or dumb, commercially we're all as green as grass,
But we want to be chemists.
Bum! Bum!
We want to be chemists.

It would be much easier to discuss what kind of chemists industry wants if we were sure at this point that we all agreed on the answer to the major question propounded in our first chapter, namely, What is a chemist? But I don't suppose

all of us ever will think exactly the same about that question. Some people, as we have suggested before, see a tired-looking soul who makes umpty-ump dozen polarimeter readings a day, more or less, in somebody's beet-sugar factory and they speak of him as being not just that factory's "chemist," but perhaps its "chief chemist."

Other people will know a somewhat frowsy being who shows unmistakable signs of being not altogether housebroken socially, and, because in his waking hours he is a denizen of some disordered laboratory, they classify him in their minds as a chemist.

Neither of these types, however, quite represents the person we are about to consider. The man we propose to discuss here is the one who has had a college training in chemistry or chemical engineering and who either is about to start to work on his first job or else has been out of school only a few years, perhaps in commercial work or maybe in teaching, and is contemplating a new connection in industrial work.

One way of starting our discussion about the kind of chemists industry wants is to consider

some of the questions that are asked of candidates by those men who do the scouting work for large employers. Whether or not such "scouts" know what they are doing may still be an open question, but the fact remains that when they sniff around a college class of twenty or more individuals and pick out the two or three they think are best suited to the needs of their particular organizations, they do their picking largely on the kind of answers they get to their questioning.

Oddly enough these men, who come to our educational institutions announcing that they are interested in hiring some chemists, are not, as a matter of fact, looking for chemists at all. Rather they are looking for a type of man. To be sure, they want the men they seek to have a chemical or a chemical engineering training, but, more important, they want him to be the right sort of an individual. They want him not only to be capable of doing the job they have in mind for him to start on, but they want him to be able to keep growing to meet additional responsibilities as they come his way. If possible, they want him to be the kind of person who will never find

himself against a stone wall, so far as promotions are concerned, either because of lack of capacity or because of some personal shortcoming. This being the object of their search, what sort of questions do they put to him?

One of the first and most important things they ask is, "What kind of a student have you been?" or "What sort of a scholastic record have you made?" They believe they want a high type of intelligence and they think that ordinarily a man with such intelligence will have made a good scholastic record. If the student can answer that he has made mostly A's and B's with maybe only an occasional C, that is a good sign. If he can say he was in the top 5 or 10 per cent of his class, that is a healthy indication. If he has been able to rate No. 1 in his class, that registers mighty heavily in his favor. If he was only average, he is still not out of the running, of course, but he is going to have to show some other highly desirable characteristics to compensate for his lack of scholastic leadership. And if his grades averaged below C, well, he may, in later life, develop to be the Pud'n'head Jones whose career

is sometimes cited as proof that the boys who are dumbbells in school succeed in a bigger way and go further when they get out into the world than do the bright boys, but he is going to have a tough time getting a good connection with a large and progressive organization to start with. Brains count. There is no doubt of it, and the best way industry has of finding out whether the prospective candidate for a job has them is by his scholastic record.

Somebody is probably wondering by this time why the *student* is asked about this. Why are not his professors questioned concerning him, or, better yet, why is not a record of his grades looked up? No doubt, if the mere facts were all one wanted to know, that would be the way to get them and, of course, the professors will be asked for their opinions and the records may be reviewed. But by asking the student himself two things are accomplished.

First, the facts about his scholastic standing are brought to light fairly accurately. Only very rarely will a man overstate his attainments on such an occasion. In fact, there is usually more trouble in

getting a fair answer to this question because of the modesty of the student than because of any tendency on his part to overrate himself.

Second, some insight is gained into the student's personal characteristics. The question, directly put, is not an easy one to answer, and the interviewer has an opportunity to see how the man being interviewed meets an unusual situation.

There are many different reactions to the question. Those individuals who are less keen do not see what the questioner is driving at. They just look blank, become confused, and their answers come in a stumbling fashion. Those who are quick to sense what is wanted are faced with the problem of telling how good they are without appearing obnoxiously "cocky" or of outlining what their shortcomings have been in a manner that will not make them lose out entirely. The candidate's response to either situation is quite likely to give some interesting insight into his characteristics.

Another question is likely to be something along this line. "What did you do around school besides get your lessons?" The answer the inter-

viewer hopes to get is that the candidate was a class officer or one of the editors of the school annual or a member of the football team or an active participant in the dramatic club or the glee club or anything that shows he lived the life of the school. Industry wants men who are interested in their environment, who want to do things with their fellows, who are alive to what is going on about them. It does not want the ingrown soul who craves seclusion and who cannot put himself into the life of which he is a part.

If the answer to this question can be that the candidate was president of this or captain of that or business manager of the other, so much the better, for, while those jobs sometimes go to the man who is willing to be a party to questionable campus politics, they more often go to the man who has a natural capacity for leadership and that, of course, is another faculty which industry wants.

Sometimes the answer to the question is, "I had to earn money and had no time for anything but that and my lessons." This is not a very good excuse. It is usually possible to earn money and

to take at least some part in the activities of the school.

It sometimes happens that a professor overhears this question and interjects a remark to the effect that he works his students so hard in his department or in his classes that they have no time for anything else but their studies; and he rather preens himself as he says it. Well, those gentlemen may be developing their students to be well-informed chemists or chemical engineers, but they are not helping, by such a point of view, to develop their students into what industry wants in the way of men. No doubt many of their students are succeeding, but it is probably in spite of the grind they have been through, not because of it. Of course, anyone who knows anything about the requirements of a training in chemistry knows that plenty of hard work is required, and no one expects such a course to smack of supervised play. On the other hand, however, it would seem that industrial chemistry can be administered to students in such a way that they can "live" and learn at the same time.

Another question often asked is, "What have you done during your vacations while you have been coming along through school?" All too often the candidate hangs his head and mumbles in shame that he never had a job of a chemical nature, and then stops as if that were the answer to the question. But it is not—far from it. No one cares much whether a recent graduate ever had a job of a chemical nature. He is not being hired as an experienced man and what little he could learn of chemical practice during the few summers he has had to get experience would not be worth such a great deal anyhow. The most important thing is, did he work? Of course, there are other things he could do that would help round out his background. Travel, for example, is worth while, but the interviewer would feel surer that the man had learned about working if he had worked his way on his travels.

Sometimes the reply has to be that the candidate went home and helped on the farm. That is not a bad answer. He did not learn much about chemical equipment, but he had to keep the mowing machine in shape and the tractor going,

and, after a few summers at that, he at least will not shy at a monkey wrench or require a special set of mimeographed instructions to prompt him to fix a piece of equipment if it happens to go wrong.

Sometimes a boy has sold books or aluminum ware or something else. If he did, he learned how to meet people, he learned to judge how they were going to react under certain conditions, and he learned how to treat them so that they would react favorably to what he was presenting to them. That is a kind of training that chemists, as a class, probably need as much as any other single sort of experience. The folks these chemists-in-training are going to work with later are very much the same sort of souls the boys would meet in summer selling, and what the young men learn in dealing with these people is going to stand them in good stead the rest of their lives.

The more varied the experience a student can get during those precious summers the better, but let it never worry anyone that during his summer vacations he did not happen to be able to get a chemical job.

And now for a question which is not ordinarily asked of a candidate but the answer to which usually has almost as much to do with the young chemist's success in a large organization as any other single thing: Can you express yourself readily, especially in writing?

If the truthful answer to that question is not "Yes," the aspiring young gentleman under consideration had better dig in with all his might and main and get himself in such shape that the answer does not have to be "No." Straight thinking is probably the most essential single thing in one's bag of tricks, but the ability to express oneself well comes a mighty close second.

Perhaps there are some people who are not going to accept this thought right away, but let us call to their attention the following points: Practically from the beginning of his industrial career the chemist is going to be writing reports and letters concerning his work. He will be trying to explain what he did, why he did it, and what results he got. He will be undertaking to marshal his facts in such a way that readers will be led to the same conclusion he has reached. Now he will come in

contact with relatively few people if he joins a large organization, and his immediate boss will be the only one he can impress with how good he really is (assuming, for the moment, that he is good). But his reports and letters lead a different life. They go through his boss's hands to others above him, and, if a man's report is a really good one on an important subject, it will fall into the hands of people whom he personally has little or no opportunity to see (or more important, to be seen by). Well-written reports mean circulating good impressions of the writer. Poorly written ones either do not get far enough to circulate any impressions or, if they do, they circulate poor ones, and, you know, if you can't be the boss's son or marry his daughter, it's up to you to get favorable attention by inducing people to think well of you.

When we started discussing this particular question we mentioned the fact that it was one that is not generally asked of the student himself. The reason is that usually it would be a foregone conclusion that he would answer "Yes," whereas, in truth and in fact, as the lawyers say, that is the

wrong answer in many cases. And, strangely enough, the question of the man's honesty has nothing to do with the matter. For some strange reason most people appear to be under the impression that what they write is pretty good whether it actually is or not.

Of course, the background for a good report is good work and without it there can be no good report. But at the risk of being boresome, or even irritating, let us urge once more that every ambitious embryonic chemist should be sure to train himself so that, if he does a good job, he can tell about it well.

So much for the questions; here are a few additional points.

While we are on the subject of making favorable impressions, we might say a word or two about the matter of personal appearance, delicate though the subject may be. What we intend to say about it you have no doubt guessed already—it is obvious. A neat appearance is an asset. Dirty fingernails, a couple of days' growth of beard, a shock of hair that needed cutting two weeks ago and still does, all are liabilities. Many an honest

heart may beat beneath a ragged vest, but everybody would feel better about it if the vest were not ragged.

Curiously enough, while all the foregoing is recognized and understood by practically everyone, there are many who seem to feel that for the technical man it does not quite apply. They apparently think the rules are suspended as far as he is concerned, and there is, in some quarters, even a rather well-defined impression that he has to look a bit grubby to prove he is the stuff of which technical men are made. One employer once refused to hire a student recommended to him by a certain professor because the student looked dirty and uncouth, all of which led the good professor to inquire whether industry expected him to run a beauty parlor along with his course in chemistry. People may let themselves look grubby for either one of two reasons. It may be that they do not know any better and that they will learn to polish themselves up a little more thoroughly later on. Or it may be that they just don't give a hoot. If it is the former, one might put up with them until they learned better. But if

it is the latter, there is not much hope, and the man who is interviewing prospects cannot always be sure which kind he is dealing with. A clean face and a neat appearance will relieve the interviewer of the necessity of wondering. The chemist-to-be can make up his mind to one thing. If he is going to insist on indulging himself in the joys of being unkempt and seedy-looking, it is probably going to cost him money. Maybe he can afford it, but certainly he should understand that it is a luxury.

Since it is men that industry wants, rather than merely chemists, someone is probably wondering why character references are not the first thing investigated. Well, sooner or later they are considered, but as a matter of fact that side of the question takes care of itself almost automatically. In the first place, the men in the schools where chemists are trained are usually men of character themselves, and it is very doubtful whether an instructor would let a man who was not all right go to an employer without giving the employer the facts about him. In the second place, men who go in for a scientific training

apparently are the kind whose characters, for the most part, are made of fairly sound stuff. Whatever the reason may be, the fact remains that among the technically trained men who have come under the writer's observation, those who were not of good character have been few and far between. Understand, the words "chemist" and "angel" are not synonymous, but the moral fiber of the technically trained as a class seems to be pretty good.

A while ago we mentioned the advantages of work during summer vacations as a partial training for industrial work. What other forms of preparation are helpful?

A certain amount of experience as a teacher seems to make for success. It is valuable for two reasons. First, as is well known though not always admitted, a teacher usually learns more from a course than the students. At least, by the time a course has been taught a number of times, the one teaching it usually has the subject matter pretty well in hand. In this way teaching experience grinds the facts of chemistry into the mind in a way that simply taking the courses cannot

do. Second, the scientist knows, or comes to know in the course of time, a lot of facts of a more or less technical nature, which other people in the organization in which he works do not know but which they should learn. The teacher is accustomed to getting ideas across to people who are not familiar with what he is telling them. He knows how to start at the proper level of understanding so his hearers will be with him, and then how to build up his thought structure in a logical and understandable way. To industrial work he brings this same ability to make his points clear.

On the other hand, too much teaching sometimes develops a frame of mind that takes for granted that the party of the first part is to be accepted as the final authority on all occasions and—well, you know how some of them get. That would be fatal in industry.

What course of study should the man preparing for an industrial career have had? Ah, many wise men have asked each other that question and then held learned conferences trying to decide on what the answer was. Fools may rush in where

angels fear to tread, but the writer of these words is not going to undertake to answer the question. He will, however, offer a few comments.

Obviously the fundamental courses of inorganic, organic, analytical, and physical chemistry, together with a thorough course in physics, are the foundation on which to build. The elementary courses in these subjects should be supplemented with advanced and more thorough courses in each of these fields. But what more?

Some knowledge of biological chemistry and bacteriology might well be included as a valuable part of the training program.

We have already pointed out the important role which the ability to express oneself plays in a person's progress. We have called attention to the fact that one is reporting on his work constantly, either orally or in writing, from the day he starts his job to the day he is fired, or, more happily, to the day he retires. Too often there is not enough attention paid to this phase of a student's training.

What about mathematics? How much of that ought one have? Well, there is another contro-

versial subject. Anyone who expresses himself very strongly on the matter is sticking his chin out, and that is always dangerous. But again, some observations may not be out of order. Personally, I have yet to meet, in industrial work, and I include here the fundamental research necessary in connection with industrial work, more than a handful of men who ever had any occasion to use calculus—and I suspect one or two of those who did use it did so for the very profound effect it was supposed to have on the men who saw them spreading integration signs around. The fact that it is used so infrequently might lead some people to feel it is an unnecessary subject. Such a conclusion, however, would seem questionable for it does have its definite place, but it should not be emphasized out of proportion to its importance. As between learning to write and learning to integrate, the former is definitely the more useful.

What about engineering training for the industrial chemist? In other words, shall the student contemplating a future in industry study chemistry or chemical engineering? That is another widely

debated question and the subject of pretty lively controversy between the chemistry and engineering departments of every educational institution large enough to harbor both factions. The participants in discussions of the subject are usually too gentlemanly to say what they really think, but, comrades, how they think!

Once upon a time I tried to get some reliable information on the subject by going to one of the largest universities in the country and asking the head of the chemistry department how the training he gave his men differed from that given by the department of chemical engineering. He explained that he taught his men chemistry. They knew the fundamental facts. They understood the controlling conditions. They were equipped to do the thinking for industry. The chemical engineers, on the other hand, were simply taught the mechanics of handling chemical materials. They could run the pumps and stills and filter presses and whatnots under instructions from the chemists.

Then I went to the head of the department of chemical engineering at the same institution and

asked him how the training he gave his men differed from that given by the department of chemistry. His answer was very simple. "We teach our men all the chemistry they give students over in the chemistry department, and in addition we teach them how to get things done." It was all on a very high plane, you understand, but it rather discourages one from making further studies into the subject. As a matter of fact, one of the most capable industrial chemists I have ever seen in action was trained as an "agricultural chemist."

Probably the interest and aptitude of the individual will have more to do with his fitness for one line of work or another than the training which is given him. Some men enjoy working with machinery—actually operating it, taking it apart, improving it. Such men make good plant development chemists whether they have an engineering training or not. Other men have an aversion to machinery. While they may understand how it works, it bores them actually to have to work it. All the engineering training in the world would not make them first-class plant

development men. Usually men of the first type are attracted to courses in chemical engineering, but if they happen to take chemistry instead they are still good men for plant development work. Fortunately the field of industrial chemistry is broad enough to offer a place for individuals of both types.

What of graduate work? Beneficial? Indispensable?

In university circles there is practically only one answer to the question of the value of graduate work that is considered sound. The keener and more alert student is advised by his teachers to take additional work by all means. In fact, there are university professors who become almost savage toward an employer who comes within their halls seeking to hire the exceptionally bright student when he has taken only his bachelor's degree. It is wrong, according to them, because such a student should go on for his Ph.D.

If all that industry wanted of men with chemical training was investigational work these professors would have much excellent argument on their side. But, as we have seen in previous

chapters, that is not all industry does want. Consequently we cannot agree with them entirely. There is something to be said on both sides of the question.

The graduate student frequently devotes part of his time to teaching while progressing with his graduate studies and in this way he gains for himself the advantages that were pointed out in our previous discussion of teaching. On the other hand, the student who does not stay for graduate work gets a head start in becoming familiar with the work of the industry in which he is to launch out and a head start in working with the people with whom he is eventually to be associated. He will have gained a certain number of years of seniority.

Again, the additional training which graduate work gives, particularly the practice gained in attacking investigational work, makes for resourcefulness, develops the imagination, and tends to remove the "lost" feeling that sometimes overwhelms the beginner on his first job of facing unknown conditions and of having to bring an answer out of the darkness into the light. But

against that, the point may be made that industry, too, offers plenty of practice in attacking investigational problems, and its problems, usually being practical ones of immediate interest, often seem more stimulating than those offered the advanced worker in a university.

A further advantage in remaining in school for graduate work is that it enables the student to enjoy much more intimate contact with the older and more experienced members of the faculty than the undergraduate student is able to have, and there is no denying that much is gained through this closer association with the men who are devoting their lives to the fundamentals of their science. But industry too has its "teachers," who can and do do much in broadening the knowledge of the "apprentice" investigators who come within the circle of their influence.

It can be cited, and sometimes is, by heads of chemistry departments that a larger percentage of their Ph.D. men succeed than of their M.S. men, and that a greater proportion of these, in turn, do well than of the bachelor-degree men.

However, this is not fair evidence on the case, and it certainly is not scientific evidence. Of course, more graduate-degree men succeed proportionately. They were only allowed to stay on for graduate work because they represented the more promising portion of their class.

Perhaps we can round out this discussion with the observation that in no field of industrial work is graduate training absolutely necessary, and the student who will force himself, at the expense of health or even disposition, to endure several years of what to him is drudgery, just to end up by being one day dubbed "Doctor," is making a mistake. If he is continuing his graduate study because somebody has told him he ought to, instead of because of his own keen interest in it, then for him it is probably not worth continuing. And as for the "Doctor," the chances are that he will be reduced to the dead level of "Doc" anyhow when he gets out, because that is the convenient handle put on most chemists by their nontechnical coworkers in industry, whether they have actually had graduate work or whether they are just plain beaker boys who never even went to college.

On the other hand, if a student taking his bachelor's degree has a genuine interest in further study and has a chance to go on for advanced work, he certainly will make no mistake in taking advantage of the opportunity. But, let us repeat, he should have a genuine interest in continuing, not a forced one.

One man in industry who had achieved at least some degree of success in his field summed up a discussion on the subject of graduate work about as follows: "I chose to remain in school for graduate work till I had satisfied the requirements for a Ph.D. and I am glad I did. On the other hand, I work for a chemist who did not take a Ph.D., and he works for a chemist who did not take a Ph.D., and he works for a man who didn't even go to college." All of which probably is some indication as to whether graduate work is essential to the success of a chemist in industry.

Chapter VI

THE KIND OF INDUSTRIES CHEMISTS WANT

We're an assorted bunch of industries that make this country's wealth.
We hire chemists.
Bum! Bum!
We hire chemists.
And, sometimes, when they fail to help our economic health,
We fire chemists.
Bum! Bum!
We fire chemists.
Now some of us need the chemists' aid in a serious, vital way,
Others might do without them, but we're pretty sure they pay,
While some of us simply keep them, but just why we couldn't say.
But we have chemists.
Bum! Bum!
We hire chemists.

When years of business depression hit the country it is probably quite out of order to raise any question as to what kind of industries chemists

want to work for. By and large the answer to the question, at such times, has to be, "Any kind that will have us." Consequently in such periods some of us lay our chemical training on the shelf, for the time being, and go to driving taxicabs or selling sandwiches as expedient, if not particularly lucrative or inspiring, occupations. However, better times always seem to come again when we have some choice as to what we shall do. Consequently we venture to put in a few words concerning the factors to be considered in making a choice.

Before we can intelligently discuss the subject of the relative merits of various industries, however, we have to decide just what we want the industry that employs us to do for us.

As a starting minimum, of course, we want it to pay us a living wage, but actually almost any industry, if it will have us at all, will do that; so suppose we take that much for granted and go on to say that we want it to hold out an opportunity for a good deal more than a living wage.

We want it to offer a "saving wage," which means not only enough to live on, but enough to

enable us to enjoy some of the worth-while things life has to offer and, in addition, enough to permit us to lay by a proper surplus. We think we would like to receive this surplus over our actual needs so that we can put some of it away and one day have a supply of money in addition to our salary coming into our coffers.

Finally, it is probable that most of us look forward to the day when we shall have saved enough so that we shall be able to be more or less independent of our salaries. Not, mind you, that, having achieved such independence, we shall want to stop working. We realize that only by keeping reasonably active can we actually remain contented and we recognize that some of the hardest working men many of us know are ones who work from choice, not necessity. But understanding all that, we still think, many of us at least, that it is going to be a soul-satisfying experience to see our independent income grow to a point where we can get along without our salaries if necessary.

In addition to a "saving" income, we want to feel reasonably sure of a continuance of our job, assuming, of course, that we do acceptable work

on it. We do not like a situation such that a whim of some official or heavy stockholder may result in all chemical division activity being suddenly suspended, with the resultant calamity of our being thrown out of our jobs. We want to feel that chemical help is sufficiently vital to our employer to make him hesitate about discontinuing it, or even curtailing it too drastically.

Now we come to a point which many people will say should have been the first and foremost of all, and perhaps it should, though to some of the rest of us it would not begin to register in importance until the points previously mentioned were properly covered. We refer to having interesting and stimulating work in congenial surroundings. This point is, of course, of tremendous importance, but the reason for not putting it first is that almost any work becomes interesting and stimulating if we throw ourselves into it and if we realize that it is getting us somewhere.

But what does it mean to be "getting somewhere"? Well, as we said before, we want to be gaining financially, and that is part of it. But we also want to be growing in the esteem of our

coworkers and our superiors. The niche which we occupy in industry may be a minor or inconspicuous one, but we do want those of our fellow men with whom we come in contact to respect what we know about our little segment of the world's work and to think well of the way we handle our job. (All of which, of course, assumes that we are doing a good piece of work in our field.)

Speaking of esteem and our relative place in the general scheme of things, it may be of interest to refer to an experience that a certain man once had when calling on a large industrial concern where he wanted to discuss a technical problem with the company's chief chemist. As one would do in such a case, he went to the main office and announced that he would like to see Dr. Blank. The lady at the reception desk eyed him with suspicion. "What are you selling?" she asked. In simple words of not over one or two syllables he informed her that he had nothing to sell, that he was connected with an industry wholly unrelated to the one on which he was calling, and that all he wanted was to discuss a technical matter with Dr. Blank. By this time she seemed to be of the opinion

that he was either vicious or crazy. Apparently visitors to see the doctor were not an everyday occurrence. "I don't think you can see him," she finally said, "I'll let you talk to a Mr. So-and-so." You can leave out the "Mr." as you read that sentence and you will have a pretty good understanding of the gentleman to whom she referred him. Mr. So-and-so was a portly, pompous person and an officer in the company. Once more the man told his story of having nothing for sale and of wanting to discuss a technical matter with the company's chief chemist. Then came a remark which probably should be regarded as a classic. Said Mr. So-and-so, "You can't see him. We keep our chemists in their place." So the man had to call on Dr. Blank at his home that evening.

Unpleasant as this story is, it does have a happy ending, for it can be reported that the concern with which Mr. So-and-so was connected has gone into bankruptcy. But the point of view that a chemist is a person to be kept in his place, and that place a minor one, is, unfortunately, one which some industries still hold. Of course, it is probably our own fault in part, for many of us have insisted on

regarding our science as something that we had to keep with ourselves in our laboratories. Instead of looking upon it as a tool to aid us in any field of industry where men find employment, whether that field be production, buying, selling, or what-not, we have thought of it as an end in itself. But there is more to it than that. Industry's lack of regard for the chemist cannot be entirely blamed on the chemist himself. For some reason business, in most instances at least, gives its better prizes not to the chemist who figures out the whys and wherefores of things, but to the man who takes that information and uses it to run the factory or to sell the goods. It may not be fair, but it is a fact nevertheless, and it probably will not be corrected until a larger number of chemists have advanced to positions of responsibility and have been able to recognize that a great many different kinds of jobs can be advantageously filled by men with chemical training.

But we have gotten away from our theme. You remember we were discussing what we wanted the industry for which we worked to give us, and now

that we have covered that, let us see what type of business can give it to us.

The first thing we wanted was a living wage, and, since almost any old business can cough up that much for us, there is no choice among industries from that angle.

Our second point was the saving wage; any successful industry can offer that, too, if it wants to. It must, of course, be successful or it cannot afford anything beyond the lowest wage, and also it takes success to make an industry generous-minded. But the "if it wants to" part is important. If one is considering joining a company, probably the best way to judge how well the organization under consideration is likely to take care of him is to see what it has done for the employees who have preceded him. If they have fared well, it is reasonably certain that he will.

Speaking of generous-mindedness, some organizations go so far as to provide pensions for their old employees, thus assuring them of eventual independence of their earnings, entirely aside from whether they save anything else or not. Some companies provide a sick benefit relief that tides

over the hard periods when illness overtakes the employee and makes it impossible for him to work.

When we come to the question of feeling reasonably sure about continued employment we begin to get into a real difference in organizations. Chemistry can be an aid to a great many different kinds of industry. In some, where chemical reactions are involved in the manufacture of the products, chemical aid is indispensable if that industry is to function efficiently and keep pace in its development with its competitors. In others, particularly those engaged in mechanical manufacture, chemistry is a valuable aid in selecting proper raw materials and keeping them up to proper standards, but it is not the fundamental part of the work. In still other businesses, it is painful to recite, the chief function of the chemist apparently is to give the company's advertising department something to write about.

Continuity of employment in the first class is relatively certain, because the business just cannot go on without chemically trained men. In the second class the likelihood of continued activity

is good, for chemical aid is of importance and will probably not be done away with so long as business remains reasonably good. In the third class the permanence of the job is likely to depend on how fresh the eggs were that some major-domo had for breakfast, a situation that is a gamble, to say the least.

Now as to the "getting somewhere" part of our discussion. This divides itself up along very much the same lines as the continuity of employment did. In an industry that is dependent on chemical reactions, the chemist will naturally be more highly regarded than in other industries. Often he is the man who makes things go, always he is the man who knows why they go, who may get the credit when they are made to go right (and who is sure to get something else when they go wrong). He is in the eyes and minds of the men who decide on promotions and his chances of being well regarded are comparatively good. His field for development is not confined to chemical work, and, if he develops an interest in production or sales or buying or accounting, promotion may lie ahead of him in any of those fields.

In the mechanical industries where chemistry is used, although it may be regarded as a valuable and highly respected tool, it does not hold the center of the stage. The men there who are making the "big decisions" are more likely to be mechanically trained, not chemically. While such industries no doubt offer many excellent opportunities, they would seem to rank second to those in which chemistry holds the key position.

And in the third type of industry, where the chemist is something to talk about, he is likely to be talked about within the organization as well as without—and that not particularly to his credit. While even in such an organization he can do a considerable amount of good if given an opportunity, he is regarded as an intruder in most directions, his presence is resented by the men for whom he could do the most good, and his chances of getting to first base are not much above zero.

Chapter VII

THE CHEMIST IN WARTIME

Some create explosives that are simply fit to kill.
But we're chemists.
Boom! Boom!*
We're still chemists.
While others hide a foundry, make it seem a verdant hill.
We're the chemists.
Boom! Boom!
Always chemists.
And some make poison gases, others, dehydrated fruit,
And some seek raw materials that we can substitute
For those we used to use before we had to stop to shoot.
But we're chemists.
Boom! Boom!
We're all chemists.

In time of war, the chemist, like other technically trained men, is likely really to come into his own. Not only are his services needed in direct military matters, but his usefulness in many varied fields of production becomes greater than ever.

* Regarded as more appropriate for wartime than the "Bum! Bum!" of previous chapters.

To consider first the direct war effort, we find research and development work of the type discussed in previous chapters applied to countless military problems. In fact, about the only kind of chemical activity that is not applied to such problems in one way or another is products service work. This does not have such an immediate bearing on direct war studies, for when we are making explosives or poison gases we don't care so much whether the products *please* the customer so long as they *kill* him. Similarly the customer's likes and dislikes are of less importance in the case of a good many of the other war products. Later we shall find that products service work does have its important place in the wartime economy, but it is not on strictly wartime products.

Among the war problems of the chemist some are well known, while others are of such a secret nature that only a handful of people even know they are being worked on.

Of the more obvious studies, poison gas and protection against poison gas are two that immediately come to mind. It is tragic to think that

groups of intelligent, civilized men have to devote their best thinking to problems as fiendish as these, but when fiends are loose in the world we have to be prepared to meet the situations that they may impose upon us, so we try to develop the most telling gases we can and at the same time we try to work out the most effective defense against possible enemy gases.

Another field of war studies has to do with camouflage. Many types of coatings and coverings are used in this work. The matter of selecting the most effective ones, making them available where they are needed and when they are needed, finding preservatives which will keep them fresh looking so they will really "hide," these and many other problems call for solution.

A third field of study has to do with foods. This subject is particularly critical in the present war because the distances over which supplies must be transported are so tremendous and the conditions under which they are to be used are so diverse. If you will remember for a moment the difference between butter that has just come out of the icebox and butter that has stood on the

kitchen table for some time on a hot summer day, you will have an example of the kind of problem that comes up when some of our men are fighting in the torrid tropics while others are in the icy north. The food we send them must be adapted to meet the conditions under which they are operating, and this presents many problems for the chemist—problems of formulation, packaging, and preservation, to mention but a few.

Synthetic rubber is another field that has given chemists a chance to contribute to the war effort. This particular subject has been such a plum for the politicians, columnists, and publicity seekers that we are apt to forget that behind it all a considerable body of earnest men are learning the facts of synthetic rubber and applying them to the solution of our badly tangled rubber problem.

The many new war machines which have been developed have brought problems in their wake for the chemist. For example, the temperatures encountered by a plane at 20,000 feet are quite different from those prevalent at lower altitudes. Lubricants have to lubricate whether the atmosphere is hot or cold, but you will recall that the

lubricant in your car is apt to be quite different if the car is in a warm garage than it is if you park it out on the street some cold night. Lubricants and shock-absorber liquids have to be found which show relatively slight viscosity changes with change of temperature.

The foregoing represent but a few of the types of problems that the direct military effort presents to the chemist. Numerous others could be cited, but in addition to all of these, the chemical problems of normal industry also mount many fold in wartime. Probably "normal industry" is the wrong expression, for in war no industry is normal. What we are really referring to is that part of industry which is trying to supply normal civilian requirements.

Because the necessities of war require the diversion of immense quantities of materials to the war effort and because importation of many raw materials ceases when war breaks out, there develop acute shortages of raw materials for general manufacturing use.

You will recall that in previous chapters we discussed the chemist's search for new raw

materials to make his product better or to make it cheaper. In war his search becomes a mad hunt for raw materials just to make his product. He awakes one morning to find that his usual raw material, which came from the Malay Peninsula or the Philippine Islands, has ceased to come. Or he may find that a domestic material has become so important to the war effort that the government says to him, "You can't have any more." Even if his firm was forehanded and laid in a supply just in case a shortage might develop, the government may come in and say not only, "You can't have any more," but even, "You can't keep what you already have."

Now while practically everyone is willing, and even eager, to make whatever contribution he can to the war effort, nevertheless the shortage of raw materials makes life a touch-and-go affair for the chemist in industry. "Here today and gone tomorrow" may apply to his raw materials, to his packaging supplies, to anything he buys. The substitute he finds when he first studies a shortage problem may be the commodity that is no longer available a week later, so he looks for substitutes

for substitutes. He studies alternate supplies with a frenzy that makes his prewar search for new raw materials look like sheer dawdling.

It is in evaluating the effects of substitutions that the chemist in products service work finds his place of usefulness in wartime. His is the responsibility of seeing to it that, in spite of the raw-material substitutions that have to be made, the performance of products remains up to the prewar standards or as near to them as substitute materials will permit. With the innumerable changes that the critical conditions of wartime necessitate, the work of making sure that products remain of suitable quality becomes a job of constant vigilance, and the chemist trained in products service work is particularly well qualified to evaluate the effect of changes and to make sure that quality does not suffer.

This may be a good point at which to inject a slightly encouraging note into our discussion. While our war studies and the hectic search for suitable materials do mean a tremendous amount of work, they result in a corresponding increase in our learning about the properties of many sub-

stances. As a result, when peace finally comes and our newly accumulated knowledge can be directed toward satisfying peacetime wants, we are going to have substantial improvements on many of the products we buy and in addition we shall have a whole host of new products that would not have been developed had not necessity spurred us on to our feverish war time pitch.

Before we close our discussion of the chemist in war, it would seem worth while to make one observation that may be helpful to some. Because of the big increase in chemical problems that require solution in wartime, the number of positions available for chemists increases also. Now, while jumping around from job to job has never been a very effective way of improving one's professional standing, nevertheless there are always some men who have, for one reason or another, got themselves into jobs for which they are not really very well suited or which do not bring them the progress they feel is due them. For such persons the increased need for chemical help offers an opportunity to locate a more congenial or more promising connection. This is by no means a

suggestion to anyone to make a change without giving the matter very serious thought or to leap without looking, but it does seem proper to point out that, if one feels he should make a change in his position, a good time to do it is when there are numerous other jobs from which to choose.

When one reflects a little over the increased demands for chemists in wartime, he gets a sort of a feeling of satisfaction over his profession that he may sometimes miss in normal times. If people turn to us when the going is hard and there are lots of difficult things to be done, shouldn't that give us just a little "lift"? Somehow it seems good to know that the training that has so patiently been given chemists can enable them to take the wide variety of problems folks need to have solved and come up so often with helpful answers.

L'ENVOI

(whatever that is)

What is a chemist? Well, here we are right back at the beginning again and we haven't yet set down a definition. We have, however, seen some of the diversified lines of work in which the chemist can make himself useful. We have learned something of the characteristics that help make him valuable and a little something, alas, of some of the qualities that handicap him. What we have really seen is that his possibilities for usefulness cover so many fields that the task of telling in a few words just what he is becomes an impossible one. We can, however, conclude with the observation that a chemist is more or less a human being, though not always behaving like one, who is going to come to be welcomed in more and more fields of business activity and industry as people learn more about him and as he in turn learns more about people.